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**DEVELOPMENT OF A FUNCTIONAL FOOD
INGREDIENT USING EXTRUSION
PROCESSING TECHNOLOGY**

A THESIS

PRESENTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

**MASTER OF TECHNOLOGY
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ABSTRACT

This project aimed to develop a puffed “functional food” cereal ingredient that could subsequently be used in muesli bar products and potentially be on sold to breakfast cereal manufacturers. This ingredient was to contain nutrients that provided heart health benefits and also to possess good textural properties and to have an acceptable taste. Extrusion processing was used to produce the ingredient; extrusion processing transformed the raw materials used into a more palatable and texturally acceptable form and changed the nutritional quality.

The decision as to which nutrients to include in the ingredient required consideration of efficacy, regulatory and consumer and market factors. A literature review was undertaken to identify potential nutrients that would have heart health efficacy, meet regulatory guidelines and still be acceptable to consumers. A qualitative consumer study was conducted to gauge consumer awareness of the nutrients investigated and the desirability for these ingredients to be included in a bar benefiting heart health.

The main heart health nutrient selected for use in the puffed muesli ingredient, based on the results of screening, was soluble fibre. The source of soluble fibre selected was oat. The total, soluble and β -glucan (a particular form of soluble fibre) dietary fibre contents and the physical properties were of interest due to their influence on heart health benefits, product claims and sensory characteristics.

The effect of formulation (starch level, starch type), enzyme treatment and extruder processing settings on the fibre content and physical properties of the puffed ingredient was investigated. It was found that soluble fibre increased during the extrusion process, partially at the expense of insoluble dietary fibre. However, β -glucan was found to decrease during processing. The level of starch in the formulation was found to have the most significant effect on both the physical and nutritional properties. Increasing the level of starch had a positive effect on the physical properties, but decreased dietary fibre levels.

The puffed extrusion product contained a low level of β -glucan and a moderate level of total and soluble dietary fibre. A number of recommendations are presented concerning the feasibility of commercialisation, ingredient supplementation requirements and further research associated with the optimisation of the formulation and extrusion processing conditions.

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LIST OF ABBREVIATIONS

AA	Arachidonic acid
ALA	Alpha-linolenic acid
ANZFA	Australia New Zealand Food Safety Authority (renamed FSANZ)
CHD	Coronary Heart Disease
CIAA	Confederation of Food and Drink Industries of the European Union
CMC	Carboxymethyl cellulose
DHA	Docosahexanoic acid
Dwb	Dry Weight Basis
EPA	Eicopentaenoic acid
EU	European Union
FA	Fatty acid
FDA	Food and Drug Administration (food regulatory authority in the United States)
FDAMA	Food and Drug Modernisation Act (in the United States)
Feed rate rpm	is the number of revolutions of the feed conveying screws per minute
FOSHU	Foods for Specified Health Use (a regulatory framework in Japan)
FSANZ	Food Safety Australia New Zealand, (New Zealand and Australian Food Regulation Authority) formerly ANZFA
GE	Genetic Engineering
GM	Genetic Modification
GI	Glycaemic Index
HDL	High density lipoprotein (cholesterol)
ISSFAL	The International Society for the Study of Fatty Acids and Lipids)
LA	Linoleic acid
LDL	Low density lipoprotein (cholesterol)
LFRA	Leatherhead Food Research Association
mm	Millimetres
mmolL ⁻¹	units for blood cholesterol concentration
MUFA	Monounsaturated fatty acid
MUHEC	Massey University Human Ethics Committee
<i>n</i> -3	Omega-3 (polyunsaturated fatty acid)

<i>n-6</i>	Omega-6 (polyunsaturated fatty acid)
NHF Tick	National Heart Foundation approved Tick symbol
NHF	National Heart Foundation
N.I.P	Nutrition Information Panel
NLEA	Nutrition Labelling and Education Act (in the United States)
NZHIS	New Zealand Health Information Service
PUFA	Polyunsaturated fatty acid
rpm	Number of rotations of the screw per minute.
RS	Resistant Starch
RS1	Physically Inaccessible starch (a classification of resistant starch)
RS2	Resistant Starch granules (a classification of resistant starch)
RS3	Retrograded Starch
SFA	Saturated fatty acid
TFA	Trans Fatty Acids
TG	Triglyceride (generally referred to as plasma triglycerides)
UK	United Kingdom
US	United States of America
β -glucan	(1-3)(1-4) β -D-glucan (a form of soluble dietary fibre present in oats)

1. INTRODUCTION

Functional foods are generally considered to be foods that provide a health or physiological benefit beyond normal nutrition (Hasler, 1998). The market for functional foods is growing, both in New Zealand and overseas. Functional food products may be classified on a continuum between conventional food products and pharmaceutical drugs. It remains a 'grey' area in the way that functional foods are both classified and regulated. The regulatory framework (food regulations, dietary supplement regulations and codes of practice) varies between countries, as do the types of allowed claims.

The functional foods market is an area that the sponsoring company of this project, Nice and Natural Ltd., would like to pursue with the snack bar products that they manufacture.

Marketing foods as having functional benefits is considered a way to increase market share and the value of product sales. However, the success of functional foods products has been mixed hence there are a number of important product, regulatory and marketing factors to consider. These factors include product sensory attributes, selection of a desired health or physiological benefit, efficacy, regulatory allowances and claims and the adoption of suitable positioning and communication strategy such that consumers understand the functional benefit and are prepared to purchase the product.

Most extruded cereal ingredients that are readily available, such as rice bubbles and wheat based ingredients, contribute favourably to product texture and provide bulk in bar products, but often deliver very little health benefit. Whereas, many ingredients that provide functional benefits have poor taste and textural properties making them undesirable for use in food products without modification. For example, soy protein lowers cholesterol, but contains bitter compounds and contributes to a gritty mouth-feel. Modification of functional ingredients may allow them to be incorporated without undesirable sensory consequences. Thus it was the aim of this product development project to develop a functional cereal food ingredient that would provide appropriate health benefits for inclusion in snack bars, and in particular in a heart healthy muesli

bar. The ingredient could possibly also be sold to cereal manufacturers for inclusion in mueslis as well.

Extrusion technology can be used to transform functional raw materials into an ingredient with desirable textural and taste characteristics. However, it is possible that extrusion may change some of the nutritional properties of the raw ingredients, so this must also be investigated.

The health condition selected as the focus for this project was coronary heart disease. Coronary heart disease is a major public health problem in New Zealand. Ischaemic Heart Disease was the second highest cause of death of New Zealanders in 1998 (NZHIS, 2003). It is therefore anticipated that consumers may be responsive to purchasing products marketed as benefiting heart health. Although a number of whole foods may be incorporated into a 'heart friendly diet', it is also possible to use technology (in this case, extrusion technology) to produce foods or ingredients with enhanced levels of nutrients identified as benefiting heart health in the context of the present NZ diet. Since few snack food products are marketed as heart healthy in New Zealand, the opportunity exists to commercialise such a product.

Hence, the snack bar shall be marketed primarily within the Australasian market and potentially in the United States where heart health claims are permitted. In the development of this ingredient the requirements such as regulatory claims for both the Australasian and US markets have been considered.

The main objectives of this research were to:

1. Identify suitable raw materials for inclusion in the proposed puffed snack from a heart health perspective and from an extrusion perspective.
2. Examine the food and drug regulations in Australasia and North America to determine whether there were any ingredient restrictions and to ascertain what health claims were permitted in the two markets.
3. Consult the New Zealand Heart Foundation to find out what restrictions they might place on the proposed product and what claims they would allow given the fact that the company wished to have the endorsement of the Heart Foundation for this new product.

4. To carry out a comprehensive market survey to find out what heart health bars are available in the proposed markets and the claims that manufacturers' of these products were making, together with any product specific information such as formulations, pack sizes, prices etc.
5. To carry out a small focus group study to ascertain potential customers views about and understanding of a number of proposed muesli bar ingredients and whether these consumers would purchase muesli bars that contained the proposed puffed ingredient.
6. To determine the extrusion parameters that would have a major impact on the proposed product and to then investigate the effect of these parameters together with formulation changes on the nutritional and physical properties of the proposed puffed ingredient.

2. FUNCTIONAL FOODS MARKET

This section firstly provides an overview of the global functional foods market, giving an indication of the market size and the main areas of activity in major markets (US, Europe, Japan and Australia). It then focuses on the heart health market (size, growth and activity) and provides an insight into the heart health cereals and cereal bar category, the focus for this project. Since New Zealand sales data was not readily available and the Australian market was similar to the New Zealand market, Australian data was used as a basis for predicting the size of the New Zealand market. The author's observations of functional food products on the New Zealand market are also given. Finally, the market players in the functional foods market, strategic options and important consumer marketing issues are discussed.

2.1 Market Size

Functional food is often described as a 'hot trend' in the food sector and is showing strong growth in most established processed food markets. The opportunity exists to enter a market that boasts high margins compared to the mature and declining markets of traditional food segments (Zammer, 2000). Therefore, marketing a cereal bar with functional benefits may provide Nice and Natural Ltd with an opportunity to further expand the rapidly expanding muesli bar market. Nice and Natural do not make breakfast cereals, and are unlikely to in the near future. However, the proposed ingredient may also enable breakfast cereal manufacturers with an opportunity to kickstart their rather static market segment. Therefore, marketing a cereal bar or an ingredient with functional benefits for inclusion in breakfast cereal may provide the opportunity to sustain higher profit margins than the margins sustained for their standard cereal bars and hence increase Nice and Natural Ltd.'s overall profitability.

Estimates of the market size vary greatly between market research reports, depending on the definition used to categorise functional foods and the methodologies used to collect sales data (Heasman and Mellentin, 2002). Limiting the definition to "food and drinks that make a specific health claim on-pack or in advertising" the combined market value of Europe, US, Japan and Australia was estimated to be \$5.7 billion in 1999

(Hilliam and Young, 2000). If a broader definition is used, and healthy foods not necessarily making health claims (but often perceived as functional) are included, the market estimate rises to over \$30 billion (Hilliam and Young, 2000). On the basis of the above trends the size of the functional foods market in New Zealand (on a population basis) could be expected to be between \$36-\$200 million depending on which definition was used. A breakdown of these figures for selected countries is shown below in Table 2.1. Growth rate estimates vary between 8% and 14% per annum (Heasman and Mellentin, 2002). However, these figures can be misleading due to the nature of functional food marketing and the frequent leveraging of hidden assets causing established food products to become “functional” overnight (Heasman and Mellentin, 2002). Despite the difficulty in quantifying the growth, the functional food market is one of considerable activity, yet still in the early growth stage.

Table 2.1: International Market for Functional Foods in Selected Countries, 1999

	<i>Strict definition (\$ billion)</i>	<i>Broad definition (\$ billion)</i>
Europe	1.79	4 - 8
US	1.80	15
Japan	2.13	14
Australia	0.05	N/A
Total	5.77	33+

Source: Leatherhead Food RA/various (Hilliam and Young, 2000).

2.2 Market situation and product trends

The major markets have developed in rather different ways, with different health propositions dominating each market. The major trends of the European, US, Japanese and Australian markets will be outlined briefly.

2.2.1. United States

One of the most significant functional food successes in the United States (US) has been the new category creation of the energy and nutrition bar market, estimated to be valued at >US \$600million in 2000, double the value of the market in 1997 (Heasman and Mellentin, 2002). This market grew extremely rapidly (30% annual growth) from a market dominated by small entrepreneurs in 1998 to a market now dominated by large multinational companies including Nestle, Kraft, General Mills and Unilever.

The US functional food market is dominated by anti-cancer products and the main functional ingredients in these products are herbs and botanicals. Many of the products launched fit somewhere between dietary supplements and food products, perhaps influenced by the strong interest in dietary supplements (Hilliam and Young, 2000). There is also interest in heart-benefit-products, particularly cholesterol lowering products, driven by FDA approved claims for heart health (LFRA, 2001). Joint ventures between food and ingredient companies and food and pharmaceutical companies and acquisitions of smaller companies by the major companies have been common in the US industry (Hilliam and Young, 2000).

2.2.2. Europe

The UK, French and German markets were the most sizeable functional foods markets in Europe in 1999 (Hilliam and Young, 2000). Finland has also seen much activity, as the pioneer of cholesterol lowering spreads containing plant sterols. The European functional foods market was initially highly fragmented, but has since experienced growth in pan-European brands.

Functional dairy products, particularly probiotic yoghurts and drinks, dominate in Europe, accounting for 72% (value share) of the total functional foods market in 1999 (Hilliam and Young, 2000). Functional spreads was the next largest sector with 14% value share in 1999. The bakery and cereal sector comprised mainly of specialist nutritional brands. Activity in this sector has included vitamin and mineral fortification, prebiotics and in the cereal market repositioning of products and marketing based on health benefits, particularly oat based products bearing cholesterol lowering claims (Hilliam and Young, 2000).

There has been some activity in heart health, particularly with phytosterol spreads in addition to some omega-3 containing products. However, some European countries have seen more activity than others (LFRA, 2001).

2.2.3. Japan

The Japanese market is long established in functional foods and includes most sectors of the food and drink market. The main area of interest to Japanese consumers has been

gut health. Japanese consumers are entirely different to those of western cultures with a greater awareness of food and health. Many products do not make specific claims, but rely on consumer knowledge of functional additives (LFRA, 2001). The Japanese regulate health claims under a FOSHU (foods approved to carry claims) system, with the number of FOSHU approved products increasing. Yet FOSHU products comprise only 15% of the total functional foods market in Japan. Although there are a number of FOSHU claims for cholesterol moderation, activity in this area has been fairly limited. Several products that regulate blood pressure have emerged however.

2.2.4. Australia

The Australian market has seen activity in many sectors including fortified bread, cereals, functional drinks and cholesterol lowering spreads, with much of the development from domestic companies such as Goodman Fielder. Australia has been a key region in heart benefit foods with the launch of a phytosterol range of products and Healthwise heart health cereals (Hilliam and Young, 2000).

2.2.5. New Zealand

Numerous functional food products are currently available in the New Zealand market. Areas of activity include vitamin and mineral fortification, particularly calcium and vitamin C, probiotic dairy products, fibre (particularly in the bread, cereal and bakery sectors), plant sterols which are limited to spreads under the FSANZ food regulations and essential fatty acids (omega-3 and omega-6). There is also a large market dedicated to diet/slimming and sports supplements.

Several niche heart health benefit products have emerged on the New Zealand market and the number of products marketed based on heart benefits is increasing. In addition, many conventional food products are endorsed by the National Heart Foundation (NHF) under the 'Pick the Tick' program. Functional heart benefit products currently available in the New Zealand market are outlined in Table 2.2. These products are making structure-function claims and in some cases borderline health claims. All of these products except Metamucil carry the NHF Tick, and prices range from being similarly priced to standard products to as much as four times the price of their standard counterparts. Product claims and price comparisons are outlined in Table 2.2 below. To the knowledge of this researcher, there are currently no snack bars or snack food

products that are promoted on heart health in the New Zealand market, nor are there any cereal bars that are endorsed by the Heart Foundation under the Tick program.

Table 2.2: Products Promoted on Heart Health Basis in the New Zealand Market

<i>Product</i>	<i>Claim</i>	<i>Price Premium</i>
Flora Proactiv.	"with natural plant sterols which reduce cholesterol uptake"	Approx. 4 × price of standard Flora and 2.7-2.9 × price of olive oil spreads
Logicol	"with plant derived ingredients that lower absorption" "source of omega-3 and 6 nutrients"	3.5- 4 × price of standard Meadowlea; approx 2.5 × price of olive oil spreads.
Meadowlea Hi-Omega	"A rich source of long chain omega-3* canola spread with Heart Benefits" *Long chain omega-3 has been shown to help maintain a HEALTHY CARDIOVASCULAR SYSTEM & promote general wellbeing when used in conjunction with a healthy balanced diet"	2 × standard Meadowlea; 1.3 × olive oil spreads
Tip Top UP Bread	"with Omega-3 DHA" Back panel: Heart – The Heart Foundation recommends we include sources of Omega-3 DHA as part of a healthy eating pattern	Negligible (2%)
Burgen Oatbran and Honey	"For your Heart" Back Panel: Burgen Oatbran and Honey is packed with natural ingredients including wholegrains, oatbran and folate that are beneficial for maintaining a healthy heart	Negligible
Metamucil	"Metamucil with 100% natural psyllium fibre. Fibre for regulatory and can help lower cholesterol levels" Side panel: Diets low in saturated fat and cholesterol that include 7grams of soluble fibre from psyllium husk as in Metamucil, may lower cholesterol levels. Reductions in cholesterol levels may contribute to reducing the risk of heart disease.	Priced as a supplement \$21.95 for 336g (48 doses)

Positioning

Functional food products may be positioned on a continuum from conventional food products to pharmaceutical drugs. The positioning of the previously mentioned available products is illustrated in Figure 2.1 below. Competition exists not only from other food products, but dietary supplements and medical drugs as well (Childs, 2001).

Figure 2.1: Positioning of Products Promoted on Heart Health in the New Zealand Market



2.3 Medical Conditions of Importance in the Development of Functional Foods

Heart disease (Ischaemic, hypertension and other forms of heart disease combined) was the most common cause of death in both males (29.7% of deaths) and females (27.4% of deaths) in 1999. This was closely followed by cancer which accounted for 28.3% of male deaths and 26.0% of female deaths in 1999 (NZHIS, 2003).

From a survey conducted in Europe by the Leatherhead Food Research Association (LFRA) in 2000 it was found that heart disease was regarded to be the most influential medical condition in the development of functional foods over the 5 year period 2000-2005. Over 94% of respondents stated that heart disease would be very or quite influential, closely followed by osteoporosis (91%), gut health (81%) and cancer (78%) (Hilliam and Young, 2000).

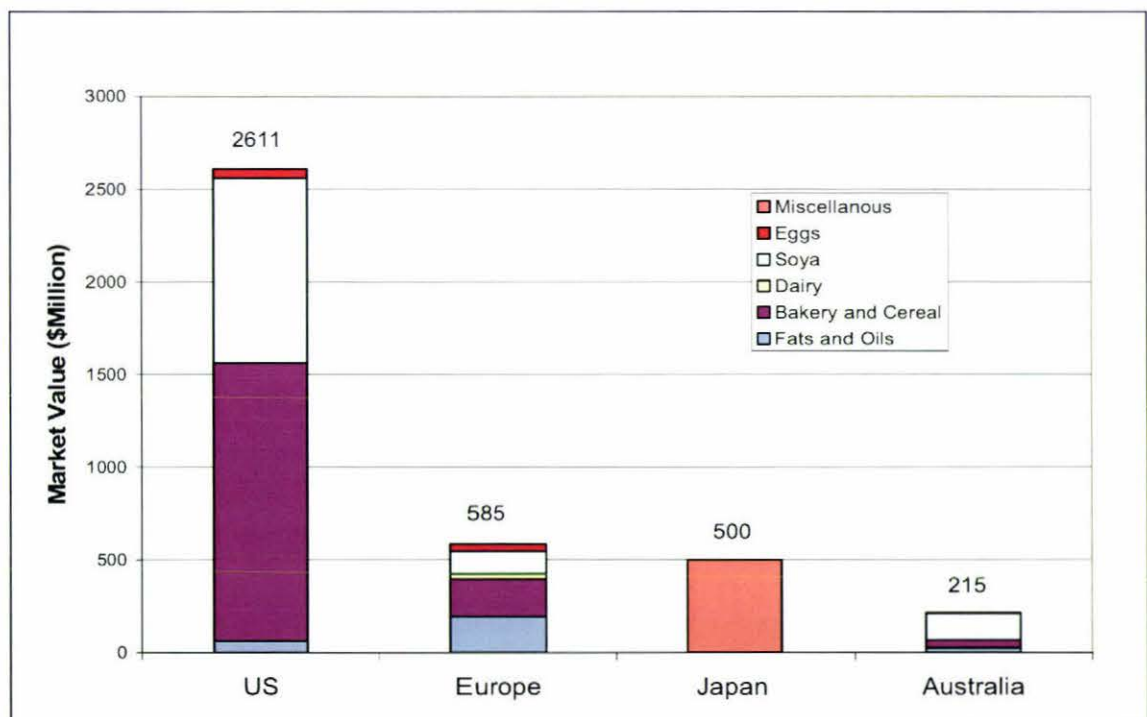
As heart disease appears to be a major concern amongst consumers in the older age groups and also because the functional foods industry recognises that producing foods to prevent heart problems is a major growth opportunity (Hilliam and Young, 2000) it was decided that heart health should be the health condition to focus on in this project.

2.4 Market for Heart Health Products

2.4.1. Market Size

The global market for heart health products was worth approximately US\$3.4 billion in 1999 and was predicted to grow by 40% to reach \$4.7 billion by 2005 (LFRA, 2001). The market size and composition for heart benefit foods in major functional food marketing countries is shown in Figure 2.2 below. As illustrated in Figure 2.2 the US dominates this market, with over \$2.6 billion sales, accounting for 76% of the global market (LFRA, 2001). The dominant categories are bakery and cereal and soya products. The Australian heart benefit food market was valued at \$215 million in 2000 – 2001 (LFRA, 2001). New Zealand has seen similar activity to Australia however the market size is likely to be proportionately smaller due to a smaller population (approximately \$43 million population basis).

Figure 2.2: Size and Composition of Heart Benefit Foods Market by Country 2000 – 2001



Source: Leatherhead Food RA (LFRA, 2001).

Indicative Australasia Market Size for Heart Health Cereal Bars

Sales data for the breakfast cereal market in Australia may provide some indication of the likely interest in functional muesli bars in the New Zealand market. Of particular

interest is the Healthwise range of products launched by Uncle Tobys (Goodman Fielder). Initially two variants were launched: 'Healthwise for Improved Heart Health' (Refer to Table 2.3, page 12 for product details) and 'Healthwise for Improved Digestive Health' (Hilliam and Young, 2000). One year after launch the range had taken only a small market share; 3.9% volume share and 6.4% value share of the bran cereals market which comprised just over 10% of the total Australian breakfast cereal market (Hilliam and Young, 2000). This indicates that the market is a small niche market only. In addition, Uncle Toby's is a well established brand (although less so in the breakfast cereal market) and has greater marketing resources than Nice and Natural Ltd, therefore the market share which could be achieved by Nice and Natural in the heart health muesli bar market is likely to be smaller (McColl, Personal Communication, 2003).

2.4.2. Predicted Growth

Leatherhead (LFRA, 2001) predicts that heart benefit foods will be one of the fastest growing functional food market segments over the next 5 years. It is the opinion of this author that the television advertising that has occurred recently in New Zealand for other heart health benefiting functional foods products (e.g. Tip Top UP omega-3 bread and Meadowlea omega-3 spread, Flora Proactiv. margarine containing plant sterols and Metamucil containing psyllium fibre), will raise consumer awareness about the nutrients they contain and have a positive effect on the growth of the market as a whole. Certainly, the 1984 Kellogg's All-Bran advertising campaign has shown the potential for the use of health claims in advertising to increase consumer awareness and change consumer behaviours (Ippolito and Mathios, 1990, cited in Williams, 1998). However, the heart health market is still small in the context of the total food market and high growth rates reflect the small initial market size (LFRA, 2001). It is important to understand that the number of consumers who purchase heart benefit food is likely to be limited to those that have heart problems or a family history of heart disease, or are interested in healthy eating and disease prevention (Wood, 1994; Wrick, 1995) rather than attracting the mass market.

2.4.3. Market Focus

The greatest number of products available and highest sale values in the heart health market has been in cholesterol lowering products, apart from Japan where blood

pressure regulation products had higher sales. The dominance of cholesterol lowering products is likely to have been influenced by the large number of US Food and Drug Administration (FDA) approved claims for cholesterol reduction, including oats, whole grains, psyllium, soya and phytosterols. However, it is expected that anti-hypertension products will also become more common (LFRA, 2001).

It is expected that cereals, bakery and soya product categories will continue to lead the global market over the next few years due to their strength in the US, with values forecast to grow by 14% to reach \$2 billion by 2005 (LFRA, 2001). However, the strongest growth is expected to be in the fats and dairy sectors, with a predicted growth rate of 825% and a forecast market value of \$250 million in 2005 (LFRA, 2001).

In general, the breakfast cereal market has concentrated on cholesterol reduction through the use of oats, psyllium, soya and whole grains. The bakery sector has concentrated on DHA omega-3 fortification; Omega-3 moderates blood lipids. The combined heart benefit cereal market for US/UK/Australia was valued at \$1.75 billion in 2001, although not all of these products make direct claims. It should be noted that the Australian cereal market has a small sector of products with heart benefit additives (such as oat bran, lecithin, psyllium) valued at \$11.3 million (LFRA, 2001), which indicates some awareness and interest. The situation is likely to be similar in New Zealand.

2.4.4. Heart Benefit Cereals and Cereal Bars

The heart health cereal bar and cereals market is discussed as these are the intended applications for the ingredient being developed in this project. Table 2.3 on the following page summarises the functional ingredients used and associated claims for selected cereal bars and cereals marketed for their heart health benefits.

Table 2.3: Summary of Selected Heart Benefit Cereal Bars and Cereals

<i>Product range</i>	<i>Brand</i>	<i>Manufacturer</i>	<i>Ingredient</i>	<i>Claimed Benefit</i>	<i>Country</i>	<i>Price Premium¹</i>	<i>Market Performance</i>
Cereal Bars	Benecol	McNeil consumer Products	Plant sterol esters	Helps lower cholesterol	US, UK	Approx. 5 x	Very good niche product
Cereal Bars	Heartbar	Cooke Pharma	Fibre, L-arginine, Phytoestrogens, antioxidants (Vit C, E, B6, B12, folate, niacin)		US		
Cereal Bars/ Cereal	Aviva	Novartis	Oat, Soya and Antioxidants	Helps lower cholesterol	UK, Switzerland	3-5 x	Poor (Range Withdrawn)
Cereal Bars	Take Heart	Altus Foods (Quaker Oats/ Novartis Joint venture now owned byPepsiCo)	Plant Sterols (Reduocol Branded)	Lowers LDL cholesterol			
Cereal bars/ Cereal	Ensemble	Kelloggs	Psyllium	FDA claim related to cholesterol reduction	Test market US (Midwest)		Poor (Range Withdrawn)
Cereal Bars/ Cereal	& More	Marks and Spencer	Soy Protein	Helps maintain healthy cholesterol levels	UK	40%	Poor
Cereal	Cheerios	General Mills	Wholegrains	Helps to maintain heart health	UK,	None	Excellent
Cereal	Axa Futura Muesli	Kungsornen	Beta-glucan	helps lower cholesterol	Sweden		
Cereal	Smart Start Soya Protein	Kelloggs	Soya protein	FDA claim related to cholesterol reduction	US		
Cereal	Healthwise	Uncle Toby's	Beta-glucan (from oats) Antioxidants (vit C and E), Folate	Help cholesterol levels Fight free radicals Protect coronary arteries	Australia		Niche (Range withdrawn due to regulatory non-compliance)

¹The price premium shown in table 2.3 is an indication of the price of the functional cereal or cereal bar product compared to a standard product of a similar nature in the given market. The actual prices were not always available in the publications this data was sourced from.

2.4.4.1. Market Performance

The market performance of functional cereals and cereal bars marketed on heart health benefits (and functional foods in general) has been variable. As shown by Table 2.3 above, numerous products marketed on heart health benefits were withdrawn a short time after test market or product launch due to poor market performance or in some instances due to regulatory ban (e.g. Uncle Toby's 'Healthwise' was withdrawn from the Australian market as the product carried a heart health claim; health claims are not permitted in Australia). Other products have performed well. Marketing a functional cereal bar/cereal product does have potential but desirable product attributes and benefits as well as the ability to market these benefits is critical.

Unsuccessful Launches

Three product launches that failed are the 'Aviva' range from Novartis, Kellogg's 'Ensemble' range and Marks and Spencers '& More', these products all carried a cholesterol lowering claim but each contained a different active ingredient. Reasons for failure are outlined in Table 2.4 on the following page.

These failures show the relative difficulty of functional foods marketing and emphasise the importance of consumer understanding, an acceptable pricing strategy and a clear communication strategy. Consumer marketing issues are discussed in section 2.7.

Table 2.4: Examples of Unsuccessful Functional Food Launches – Key Reasons for Failure

<i>Product Range</i>	<i>Key Reasons for Failure</i>
Aviva	<ul style="list-style-type: none"> • Launched under unknown brand (Lack of brand trust) • Too expensive (3-5 times the price of standard products) • Poor Taste • Packaging was highly medicalised • Timing of Television Commercial Screening (9 months after launch due to approval delay) • Retailer resistance to create a Functional Foods Section • Expectation of a mainstream market (Anon., 2001; Heasman and Mellentin, 2002)
Ensemble	<ul style="list-style-type: none"> • Poor Taste • Poor Packaging • Psyllium not seen as new (Heasman and Mellentin, 2002; Grant, 2000)
& More	<ul style="list-style-type: none"> • Cholesterol-lowering as only unique selling point • Lack of consumer concern for heart health (despite it being UK's greatest killer) • UK consumer unfamiliarity with Soy as a food ingredient • Complete lack of communication, education and information • Pricing premiums higher than the 20% premium Marks & Spencers had intended, this may have been too high (40%). (Mellentin, 2002).

Successful Launches

Two well known and very successful functional food products, marketed in very different ways are Yakult (Yakult Honsha) and Cheerios (General Mills). Yakult is a successful example of new category creation, whilst the Cheerio case study is an example of the leveraging of hidden nutritional assets (Heasman and Mellentin, 2002). The key reasons for the success of these two brands are outlined in Table 2.5 below.

Table 2.5: Examples of Successful Functional Food Launches – Key Reasons for Success

<i>Product Range</i>	<i>Key Reasons for Success</i>
Cheerios (General Mills)	<ul style="list-style-type: none"> • Established (57 year old) brand • Competitively priced • Successful nutritional marketing of whole grains
Yakult	<ul style="list-style-type: none"> • Innovative product and packaging format • Long term vision (See Functional Food Brand Building as a 5-10 year process) • Health proposition (gut health) related to consumer need • Long term commitment to consumer education (Heasman and Mellentin, 2002) • Dedication to research (Shortt, 2000)

2.5 Market Players

The functional food market is being pursued by a number of major players including pharmaceutical and food manufacturing companies. In most cases new capabilities need to be added to serve the needs of new customers (Zammer, 2000). Novartis (a multinational pharmaceutical company) believe that a functional foods company should have a strong scientific background (understanding of disease and the prevention thereof), credibility within the scientific community, regulatory knowledge, and experience in food retailing (Jay, 2000). To acquire the wide range of skills necessary, licensing and business partnerships are commonly formed, e.g. Altus Foods, a joint venture between Novartis and Quaker Oats (Zammer, 2000). Pharmaceutical companies have expertise in clinical trials and the evaluation of evidence (Zammer, 2000), but have been unsuccessful in the functional foods market due to poor communication and neglect of taste (Heasman and Mellentin, 2002). Food companies are usually consumer-centric and have experience in food product development and retailing, but may lack the scientific background (Zammer, 2000).

To date the market has been controlled by multinationals and leading food producers. It is thought that small companies have had trouble competing due to high development and promotional costs involved in this market (LFRA, 2001). Success in the functional foods market, however, should not be limited to multinationals, as it is often small companies that are the most innovative. Such companies supported by business incubators are likely to play a significant role in the future (Heasman and Mellentin, 2002). It is fair to say that Nice and Natural does not have the resources to apply for regulatory approval of health claims that are not currently permitted, nor does it have the marketing resource to successfully educate consumers on the health benefits of poorly understood ingredients. Therefore, marketing a novel, highly functional food may be unachievable at this current time. However, Nice and Natural is building a reputation with the New Zealand food trade and consumers as an innovative, functional foods producer. Consumer awareness of products can be raised considerably through shows open to the public (eg. The NZ Food Show) and other forms of advertising such as low budget TV ads and print media which the company currently uses on a regular basis. It is this researcher's opinion that Nice and Natural does have the capability of

marketing a functional food that carries pre-approved nutrition or health claims, particularly products that provide benefits that consumers have some prior awareness or knowledge of. There is also the opportunity to “piggy back” on the awareness of ingredients and their benefits raised by competitors in their advertising.

There are numerous ways to approach the functional foods market and the strategy adopted must be tailored to the type of company, capabilities (technical, scientific, manufacturing, sales and marketing), company values, credibility, risk tolerance and other factors (Zammer, 2000). Food companies may adopt an “Integrator” strategy whereby they incorporate approved functional ingredients into consumer products.

2.6 Trends driving Functional Foods Market

There are a number of factors that will shape the direction of the functional foods industry in the future, these trends and the implications for this project are outlined in Table 2.6 below.

Table 2.6: Trends driving the Functional Foods Market

<i>Trends</i> (Heasman and Mellentin, 2002).	<i>Researchers' interpretations of the implications of these trends for this project</i>
<ul style="list-style-type: none"> • Consumer Demographics The population is ageing, and diseases of ageing will increase accordingly. By 2020, the number of people in the US over 60 will have increased by 50% compared to 2002. The American Dietetic Association believe that nutritional intervention could assist 85% of elderly people whom have one or more chronic conditions. • Urbanisation means higher numbers of people are living in cities 	<p>As heart disease is an age-related condition, the number of people affected by heart disease is predicted to increase. Therefore the market for foods that benefit heart health would be expected to increase.</p> <p>The urban market is more accessible through the major retail channels and new product adoption tends to be higher in urban areas.</p>
<ul style="list-style-type: none"> • Consumer needs/desires • A shift in consumer perception to food as preventative medicine • Individualised nutritional needs, giving rise to niche markets • The number of people on specific health diets (wheat free, high protein, diabetic etc) is increasing and customised diets are becoming more common. 	<p>This consumer perception supports the functional food market. Functional food products will need to address the requirements of specific groups of people with specific health concerns. In this case, the functional food ingredient will need to address the needs of people with a heart condition or at risk of developing a heart condition.</p>
<ul style="list-style-type: none"> • A shift towards privatisation of health care and increased health care costs 	<p>This trend supports the growth of the functional foods market as a more cost effective alternative to traditional healthcare.</p>
<ul style="list-style-type: none"> • Scientific advancement and better understanding of bio-active ingredients 	<p>Scientific advancement will lead to an increased range of functional ingredients that can be used to address a wider range of health conditions and /or more solid evidence for efficacy.</p>
<ul style="list-style-type: none"> • New emerging technologies 	<p>Emerging technologies will allow sensitive functional ingredients to be processed with greater stability making functional foods a more viable option.</p>
<ul style="list-style-type: none"> • Economic pressure for the food sector to 'add value' through innovation 	<p>Functional foods will boost the economy of the foods sector through higher value exports.</p>
<ul style="list-style-type: none"> • Health claims subject to increasingly strict regulation 	<p>The lack of health claims may inhibit the growth of functional foods and strict regulation will lead to increased cost for maintaining proof of efficacy. This will have the effect of making functional foods a niche market.</p>
<ul style="list-style-type: none"> • Market response to functional foods unclear; whether the market becomes a 'mass market' or 'niche market' 	<p>The market response is likely to be linked to the price premium applied to products with high premiums driving a niche market. A niche market response will allow for higher price premiums and hence higher level functionality in products, however a mass market response may not be able to support such high premiums and hence justify the added research, development and ingredient costs of highly functional products.</p>

Demographic, consumer and healthcare trends support the need for functional food products (and hence functional ingredients such as the one being developed in this project). Scientific and technological advancements will ensure that efficacious functional foods are more achievable and allow a wider range of functional ingredients to be used. Economic pressures provide motivation for food manufacturers to produce higher value products. Strict regulations on the other hand may limit the growth of the functional foods market either because experimental costs to prove efficacy will be prohibitive and or because marketing departments will be constrained in what they say and how they say it. The industry will also have to find some way of counteracting consumers' suspicions about the truthfulness of health claims made by the functional food industry, which in turn affects their willingness to pay price premiums for functional foods. This in turn will have some affect on the degree of functionality that can be afforded in the product.

2.7 Consumer Marketing Issues

A number of consumer factors that need to be addressed in the development and marketing of functional foods products are outlined in this section.

2.7.1. Product Attributes

Taste

Good taste is a crucial element in the success of functional food products, just as it is for any food product (Heasman and Mellentin, 2002; Childs, 2001; Jay, 2000; Young, 1998). Whilst the offer of a health benefit and/or convenience may entice trial purchase, taste is the critical factor for repeat purchase. Not only should the product deliver on taste, but advertising should also emphasise positive taste attributes (Childs, 2001).

Convenience

Convenience is also paramount (Childs, 2001; Jay, 2000). Products must be easy to incorporate into consumers' normal daily routine. Therefore, the number of servings required to obtain a benefit must be realistic and the product should be suitable to consume away from home (Jay, 2000). A cereal bar is a convenient snack food that can be eaten away from home. Few consumers eat more than one bar per day, therefore a

significant benefit (eg. 25% RDI or a significant contribution towards overcoming the target markets deficiency of selected nutrient) should be obtained from one cereal bar. Product adoption may be increased by suggestion of convenient usage occasions and by highlighting substitution possibilities in advertising. It is especially important for functional food products to portray the ease of meeting dosage requirements (Childs, 2001). Suggestions of eating a heart healthy muesli bar instead of a biscuit, chips or unhealthy snack may be useful and the effect of one bar towards the overall required dosage.

Brand

The brand name should provide a clear connection to the health benefit of the food product (within the allowance of regulations), whilst ensuring that the name doesn't convey a poor taste image (Childs, 2001). A lack of understanding of the product benefit has been a major contributor in the failure of a number of functional food products (Childs, 2001; Mellentin, 2002). Branding such as 'HeartBar', whilst it clearly indicates the benefit of the bar, it medicalises the product image somewhat and may limit the target audience. A more general health branding such as "Wellness Bar", "Vitality" etc. would have a more positive healthful food image. The use of endorsements by the Heart Foundation may convey the Heart Health benefits in a more subtle way and appeal to people concerned with health in general in addition to those with or at risk of heart disease.

Other product attributes

In addition the food must be perceived to have all of the other sensory and physiological properties desired from that food. These factors include sensory properties such as product texture and appearance, price, and social acceptance (Childs, 2001).

Safety

The long-term sustainability of functional foods is highly dependent on the proof of product safety. It is increasingly common to support product introductions with comprehensive scientific evidence of nutritional and toxicological safety (LFRA, 2001). Additional considerations are necessary with the introduction of novel food products (due to the concern of allergens), in particular those that contain new protein sources, dietary macro-components, and viable microorganisms. A case-by-case evaluation of

nutritional and toxicological safety should be included. In conducting nutritional assessment it is critical to recognise the rapidly advancing knowledge on the role of disease prevention and causation (LFRA, 2001). In this project, development will utilize materials whose safety has been proven. The proof of toxicological safety is beyond the scope and resources available to Nice and Natural.

Efficacy

Nutritional benefits should be well established and dosage levels efficacious for products promoted on a nutritional or health basis (LFRA, 2001). This is important to establish and maintain credibility with medical and nutrition professionals and the educated consumer (Childs, 2001). According to Buitelaar (2000), it will be the companies that pay attention to efficacy that will survive in the functional foods market in the coming years. Companies unable to demonstrate efficacy or meet regulatory requirements will be vulnerable to criticism from consumer pressure groups (Young, 1998), and be open to negative publicity and legal action (LFRA, 2001). It is expected that the requirements to demonstrate efficacy will increase as the market and research evolves (Winkler, 1998). Clinical studies on the benefits of the bar may or may not be a practical option for Nice and Natural depending on funding support available, however it may be possible to conduct such a study in conjunction with Massey University. If clinical studies are not completed it must be accepted that the product claims will need to be more generic and specific heart health benefits can not be marketed.

2.7.2. Target Market

Functional food products should be targeted at consumers who would benefit from the product. People that are most likely to be interested in a product with heart health benefits are:

1. People that have a coronary heart condition or a family history of heart disease
2. People who are at risk (e.g. have high cholesterol) or are concerned about heart disease
3. People who are interested in healthy eating and disease prevention in general (Woods, 1994).
4. People who are not concerned about heart health are unlikely to perceive an advantage over other products (Wrick, 1995).

2.7.2.1. Positioning

Products are positioned along a continuum from mainstream to highly medicalised foods. This is reflected in the branding and packaging of functional food products. The current view is that functional food products are best positioned as everyday foods (Heasman and Mellentin, 2002). However, the obvious drawback to this is direct price comparison of standard products and their functional alternative.

Overcoming this pricing barrier is highly important, especially since high price has been one of the main reasons for market failure (or the development of a very small niche market) (Coussement, 2000) of a number of functional food products. Price premiums of functional foods range from 15-20% extra at the lower end of the scale and up to four to five times the price of a standard equivalent (Heasman and Mellentin, 2002). Although certain markets may tolerate higher premiums, e.g., Benecol has sold well in Finland, despite the cholesterol lowering spread commanding six times the price of standard margarine, many others may not (Heasman and Mellentin, 2002). It is becoming increasingly difficult to command premiums as the offering of 'heart health' has become widespread (Anon., 2002a).

Pricing can be a dilemma, as manufacturers need to charge higher prices to offset the higher development costs (Heasman and Mellentin, 2002; Beltoft, 2000), however, high premiums make products inaccessible to many consumers. From a market perspective, this creates a small niche market, and from a consumer perspective, it eliminates a large group of society who may benefit.

Utilising a product format that makes price comparison difficult is clearly a solution to this problem (Heasman and Mellentin, 2002). The most obvious example of such an innovative product format is Yakult's single-shot probiotic drinks. Marketing cereal bites may be an option to overcome this issue. It is envisaged that continual innovation in this area will be necessary in the future. Alternatively, the food marketer must justify the price premium solely by communicating a significant benefit (Heasman and Mellentin, 2002). Appropriate pricing will depend on a number of factors including: the target market, health proposition, product format and market positioning, i.e., niche or mass market.

2.7.2.2. Health Claims

The ability to make a health claim is often seen as critical to portray the benefit of functional food products and thus to the development of the functional foods market. In New Zealand, the lack of allowed health claims is a severe limiting factor. The use of health claims 'on pack' and in advertising is strictly regulated (refer to chapter 4). In New Zealand and Australia, only one health claim is currently permitted under the FSANZ regulations, and this is for the relationship between folic acid and the prevention of neural tube defects. Although a health claim framework is under investigation, it is expected that it will be approximately 5-7 years before it is fully operational. An additional limitation in the NZ and Australian heart health markets is the restriction of the use of plant stanols and plant sterol esters in only fats and oils. However, in the US, numerous health claims are permitted provided they meet specific regulatory FDA requirements. FDA heart health claims are permitted for the following ingredients/nutrients: oats, psyllium, soya, phytosterols/stanols, and wholegrains (USFDA, 2000). As different countries have different health claim codes, it is important to investigate health claim requirements for each market.

However, a US focus group study indicated that consumers do not differentiate between nutrient content claims and health claims (Levy *et al.*, 1997). In addition, the study indicated that new claims were more effective than information that was well known. The use of softer, more generic claims such as Yakults 'a healthy start to every day' have also been shown to be effective (Heasman and Mellentin, 2002). Nice and Natural could utilise permitted nutrition claims and images that suggest wellbeing as a substitute for health claims which are not permitted. It should be noted that although not all products make labeling claims (e.g. health claims, nutrient content claims), they often emphasise the benefits in TV advertising, on websites and in brochures etc.

2.7.3. Promotion

Positive Health Message

Positive health messages have much wider consumer appeal than the presentation of extensive scientific documentation as consumers are more motivated by positive health and lifestyle messages. The dairy industry is proving the success of a 'life marketing' approach with probiotics (Heasman and Mellentin, 2002). This approach may be used by Nice and Natural to market a heart healthy bar.

Communication Channels

Consumer understanding of the benefits provided by functional foods is vital in order to justify a premium price. In order to achieve understanding, effective communication is important (Grant, 2000).

Consumers obtain nutritional and health information from many different sources, including healthcare professionals, the media, pressure groups and word of mouth, it is important to manage communication with all of these groups to avoid negative publicity (Grant, 2000). Avoiding negative publicity is extremely important as product sales are greatly influenced by positive and negative media reports (Wrick, 1995). For example, reporting of a study that casts doubt over a nutrient's benefit has been shown to cause consumers to lose faith and resulted in sales decline.

Functional foods require a high level of education of the target market and a more complex, multi-channeled communication strategy. This requires a high level of investment. Separate communication channels are recommended in communicating to healthcare professionals, retailers and consumers (Jay, 2000). Communication with healthcare professionals should focus on the role of the product in human nutrition and health based on sound scientific evidence and clinical trials in order to gain support for health professional to recommend the product to patients. Retailers are interested in consumer studies that illustrate a desire for such products, marketing support, and support of healthcare professionals in order to be convinced that the products will sell. Communication to consumers should be in non-technical, consumer friendly terms that illustrate the benefit to them and appeal to their senses as a great tasting food.

To illustrate the communication efforts being made, a number of the leading UK functional food manufacturers are employing PR agencies for marketing support and advice. Yakult, one of the most successful functional food products in the market today, owes much of the growth in the UK market to its communication strategy that addressed people at all levels, including healthcare professionals. In Japan, the communication is highly personalised with the use of thousands of Yakult ladies that go door-to-door educating its clients about the importance of gut health (Heasman and Mellentin, 2002).

It is recommended that Nice and Natural also use separate communication strategies when marketing functional foods products, in the simplest form this may be achieved by producing separate brochures or sales aids for the consumer, supermarket trade and health professionals.

2.8 Summary and Conclusion

Marketing of functional foods products offers an opportunity to earn higher margins than the traditional food segment, most probably through niche marketing. Demographic, social, economic and technological trends will drive and shape this market. The combined European, American and Australasian markets were valued between US\$5.7 and US\$30 billion in 1999, which would equate to a market value in New Zealand of between \$36-200 million, and is estimated to be growing at a rate of 8-14% per year. The health propositions that dominate in the functional foods market vary between countries.

Heart benefit foods are predicted to be one of the fastest growing functional food segments over the next 5 years, hence the opportunity exists to market foods that may prevent heart problems. The heart health market was estimated to be worth \$3.4 billion in the aforementioned markets and has been predicted to grow to \$4.7 billion by 2005. The largest market for heart health products is the US, due to a combination of size, high level of interest in heart health and the presence of FDA approved heart health claims.

A number of products have already been marketed based on their heart health benefits including several cereals and cereal bars. Active ingredients that have been used in cereals and cereal bar products include plant sterol esters, oat beta-glucan, soy protein, folate, antioxidants, psyllium, fibre, L-arginine and phytoestrogens. However, most of these products are available in overseas markets only and a gap exists for such products in the local market, the primary focus of this project. However, the size of the New Zealand market is likely to be fairly small (approximately 11.75 million) and it is therefore recommended that the growing international heart health market, particularly the US market, is pursued with this product in the future.

The market success of these products has been variable. There are a number of consumer marketing issues that need to be considered in the functional foods market including product attributes (i.e. taste, texture, convenience, social acceptance), efficacy, safety and health claims and promotional issues, such as branding, positioning, and communication, all of which must be taken into account when devising a market strategy.

3. NUTRITION LITERATURE REVIEW

The primary aim of the project is to develop an ingredient that may benefit heart health. In order to define the ingredient composition of the product, a literature search was conducted to identify those nutrients that may provide heart health benefits. The simplest option would have been to follow the dietary recommendations set by the National Heart Foundation (White, 1999). However, these guidelines are based on recommendations for whole foods rather than individual nutrients that may be of interest for the development of a functional food product. It was also recognised that these recommendations are simplified for the consumer and do not always provide the totality of information required for a scientific basis. For example, the guidelines recommend increasing the consumption of foods containing dietary fibre, without acknowledging a difference between soluble and insoluble forms of fibre, although it is only soluble fibre that provides a heart health benefit.

There was a strong desire from the company for the product to be efficacious, and scientifically credible. This is a very important factor in the functional foods market from both a regulatory and health claims perspective as well as a consumer perspective. It was therefore necessary to conduct a literature review to determine nutrients of potential benefit to heart health that may be incorporated into an ingredient, as well as to identify nutrients that may have a negative effect (e.g. saturated fat, trans fatty acids and sodium) and therefore to be avoided in the ingredient formulation. The scope of the review included the strength of evidence for their benefits, any risks associated with these ingredients and/or the basic mechanism of benefit.

3.1 Overview of Nutrition and Coronary Heart Disease (CHD)

A number of factors that increase the likelihood of a coronary event have been established. Important risk factors include; personal or family history of coronary heart disease, cerebrovascular disease or peripheral vascular disease, genetic lipid disease, diabetes mellitus, hypertension, dyslipidemia, raised blood cholesterol, triglycerides, and homocysteine levels (White, 1999).

Diet can have a positive influence on a number of risk factors including lowering of total and low density lipoprotein (LDL) blood cholesterol, triglycerides and homocysteine levels and the incidence of diabetes mellitus. Other risk factors, such as genetics can not be controlled by diet.

A preliminary literature search was carried out to identify potential ingredients that could be added to a muesli bar designed to improve heart health. (Fraser, 1994; LFRA, 2001; White, 1999). This was followed by an informal pre-screen to eliminate those ingredients that were deemed to be unsuitable ingredients for inclusion in a muesli bar. The nutrients to pass the pre-screening stage included: dietary fibre, fatty acids, phytosterols, soya, folate and antioxidants (Fraser, 1994; White, 1999).

Evaluation of Evidence

The beneficial effect of nutrients on coronary health can be assessed by two outcomes; the effect on clinical endpoints (such as heart attacks, coronary deaths), or the effect on intermediates that are related to clinical endpoints, known as biomarkers. The effect on endpoints is preferable, however, such data is not always available and it can be difficult, time consuming and/or costly to collect. It is acceptable to use evidence of the effect of food on biomarkers provided there is a good correlation between the biomarkers and the disease condition. For example, a product that lowers serum cholesterol levels is generally accepted to maintain heart health (Hilliam and Young, 2000).

In considering the strength of evidence it is important to consider study type and design. There are two types of human studies; intervention and observational studies. The strongest evidence of efficacy is provided from intervention studies. In intervention studies the exposure is controlled by the investigator and therefore a causal relationship can be shown. Observational studies are not controlled by the investigator and can therefore provide evidence of an association only (Yetley, 1999). Evaluating the evidence provided by clinical studies is not a simple task. The trial conditions are highly variable, which makes studies difficult to compare. There are many factors that influence the degree of benefit that can be obtained including: subject condition (i.e. baseline cholesterol, triglycerides, gender, age), nutrient dosage, dietary controls, study design, lifestyle factors (exercise, smoking) and duration of study. Due to these

difficulties, meta-analyses and review articles were used wherever possible for this literature review; in meta-analysis carefully selected studies, taking the above considerations into account, have been analysed. Even using this approach, different conclusions are drawn from review articles by experts in their fields.

In addition, there are many debates over whether the benefit should be attributed to individual nutrients or the food as a whole. It is difficult to isolate individual nutrients, especially when a large proportion of the studies are conducted with food, where it can only be postulated which components provide the main effect. For example, much of the evidence for the benefit of omega-3 oil in relation to CHD is based on observational studies involving populations with high fish consumption. The National Heart Foundation avoids confusion over such issues by producing food based rather than nutrient based guidelines. However, for the purposes of this project it was decided it would be beneficial to focus on evidence of individual nutrients with heart health benefiting properties in order to achieve significant levels in the final cereal bar formulation. The bar would be designed to minimise nutrients that have a negative impact on heart health e.g. sodium and saturated fat. The bar would also provide other nutrients via ingredients such as dried fruit, nuts, seeds, grains typically included in cereal bars. It should be noted that this review was intended to provide information for the purposes of screening nutrients for addition to the extruded ingredient being developed. Thus, the information required is the efficacy, dosage and current New Zealand intakes.

3.2 CHD and Dietary Fibre

Serum cholesterol is well established as a major risk factor for coronary heart disease. Increasing dietary fibre is a practical dietary change people can make to reduce serum cholesterol (White, 1999).

Fibre is commonly classified into 2 categories based on water solubility: soluble and insoluble fibre. In humans, natural gel forming fibres (gums, pectins, mucilages and some hemicelluloses) are soluble, and the structural matrix fibres (lignins, cellulose and remaining hemicelluloses) are insoluble. Soluble fibres lower total and LDL cholesterol

with little or no effect on HDL cholesterol (Truswell, 2002; Glore *et al.*, 1994). Whilst some studies have shown insoluble fibre to reduce serum cholesterol and serum triglycerides, it is suggested that other healthy lifestyle factors may contribute to this finding (Jenkins *et al.*, 1998). A review by Kris-Etherton *et al.* (2002) suggests that insoluble fibres have no effect unless they displace foods containing saturated fat and cholesterol. Therefore, this review will focus on soluble fibre only.

The following section will outline the benefit, mechanism and dosage requirements of soluble fibre, the most preferred fibre source for reducing LDL cholesterol and triglycerides.

Beneficial Effect of Soluble Fibre

Most epidemiological studies have found dietary fibre consumption to be inversely related to coronary heart disease (Ripsin *et al.*, 1992; Jenkins *et al.*, 1998). But it is not clear whether a practical cholesterol lowering effect may be achieved by soluble fibre. Brown *et al.* (1999) suggest that only modest cholesterol reductions can be expected from the practical intake of soluble fibre and caution this will have only a small effect on the risk of coronary heart disease.

A comprehensive meta-analysis of 67 stringently selected clinical diet intervention studies on the cholesterol lowering effects of oat products, psyllium, pectin and guar gum (all soluble fibres) conducted by Brown *et al.* (1999) showed that soluble fibre significantly reduces total and LDL cholesterol. This is in general agreement with individual papers, in which 60-70% found a cholesterol lowering effect. High density lipoprotein (HDL) cholesterol is also minimally reduced in a high fibre diet. Soluble fibre has no significant affect on triacylglycerol concentrations. For consumption of $\leq 10\text{g}$ soluble fibre/day, total and LDL cholesterol were reduced by 0.045 and $0.057\text{mmol.L}^{-1}\text{g}^{-1}$ respectively. At higher levels significant non-linearity was observed, possibly due to reduced adherence or a biological maximum being reached (Leadbetter *et al.*, cited in Brown *et al.*, 1999). No specific dose response relationship has been shown for HDL cholesterol or triacylglycerol concentrations.

According to Brown *et al.* (1999) a soluble fibre intake of 3g/day (equivalent to 3 apples or 3 x 28g serves of oatmeal/day) showed a clear reduction in total and LDL

cholesterol levels, although total cholesterol was only reduced by 0.129mmolL^{-1} (approx 2%), which translates to an decreased incidence of coronary heart disease of only approximately 4%. Brown *et al* (1999) suggested that the major benefit of a fibre rich diet was related to other dietary factors, such as reduced fat intake rather than being due to just the soluble fibre intake. In contrast, Jenkins *et al.* (1998) suggested that 5-10g of soluble fibre per day was a practical intake and they found a 5-10% reduction in total cholesterol when evaluating a range of soluble fibres that included guar gum, pectin, locust bean gum, β -glucan at the above dose. Jenkins *et al.* (1998) also found that cholesterol reductions were higher (a synergistic effect) when slightly raised levels of monounsaturated fat were included in the diet with the 5-10 g of soluble fibre. Since the median New Zealand intake of soluble dietary fibre is 10g per day (Russell *et al.*, 1999), the higher cholesterol reductions suggested by Jenkins *et al.* (1998) may be realistic.

Some studies have found that the responsiveness of hypocholesterolemic patients to dietary fibre is greater than it is with so-called 'healthy' individuals (Anderson JW, 1995, cited in Brown *et al.*, 1999; Ripsin *et al.*, 1997, cited in Brown *et al.*, 1999). Data from a meta-analysis suggest that everyone can benefit from soluble dietary fibre (Brown *et al.*, 1999). Brown *et al.*'s (1999) meta-analysis reported no significant differences in the total cholesterol reduction between normal and hypocholesterolemic patients (concentrations $>6.20\text{mmolL}^{-1}$). Decreases in LDL-cholesterol were found to be slightly greater in studies where subjects had higher average initial cholesterol levels ($>4.3\text{mmolL}^{-1}$), -0.034 mmolL^{-1} compared to -0.015 mmolL^{-1} for subjects with initial cholesterol concentrations $<4.3\text{ mmolL}^{-1}$.

Mechanism

Several mechanisms for the cholesterol lowering effect of soluble fibre have been proposed;

1. Soluble fibre binds to bile acids in intestinal lumen causing greater fecal losses of cholesterol as bile acids. This in turn causes increased synthesis and utilisation of dietary cholesterol to counteract the losses in the bile which has a net effect of reducing circulating blood cholesterol levels (Brown *et al.*, 1999).
2. Soluble fibres fermented in the large bowel by colonic bacteria, results in production of short chain fatty acids (acetate, propionate, butyrate). According

to Brown *et al.* (1999) these short chain fatty acids inhibit hepatic cholesterol synthesis.

3. Viscous fibre may slow the absorption of foods, thereby reducing post-prandial serum insulin concentrations. Cholesterol production is reduced via mediation of HMG-CoA Reductase. (Jenkins *et al.*, 1998).

Type of soluble fibre

In the meta-analysis conducted by Brown *et al.* (1999), the type of soluble fibre did not appear to make a difference with oat, psyllium, pectin and guar all reducing total and LDL cholesterol approximately equally. Triglycerol levels were not affected by any of the forms of soluble fibre. Since there is no difference nutritionally, other factors such as allowed health claims and consumer awareness are the best deciding factors for ingredient selection for this project. Oat β -glucan was the preferred source of fibre due to an FDA approved health claim and better consumer awareness (refer to chapter 5) and lower cost of oat products. There are other types of fibre with higher soluble fibre content that are not discussed in the review due to a limited consumer awareness and health claims, e.g. sugar beet fibre.

Oat Soluble Fibre

There have been over 50 studies on the effect of oat products on serum cholesterol levels in humans. These generally indicate that oat products may lower serum cholesterol levels. Recently the US Food and Drug Administration (FDA) have approved a claim for the consumption of oat products in relation to heart disease (USFDA, 2000).

The FDA approved claim relates specifically to oat bran, rolled oats (oatmeal), and oat flour. The FDA have also recognized the soluble fibre (1-3)(1-4) β -D-glucan (β -glucan) as the main component responsible for the cholesterol lowering effect, and thus allowed a claim based on oat β -glucan content. The FDA has suggested a minimum of 3g beta-glucan per day to achieve a cholesterol lowering effect. To be eligible for a health claim a food must contain 0.75g of oat β -glucan per serve.

Dose

The FDA determined that 3g is an effective daily intake of β -glucan. However, there have been few studies to establish a dose response, which may vary between subjects groups and depend on baseline cholesterol levels. It is felt that more information on the dosage and required physiochemical characteristics is needed (Wood and Beer, 1998).

It is not only the β -glucan content, but the molecular weight and solubility of β -glucan that also influence the cholesterol lowering properties. However, this has not been addressed by the FDA (Bell *et al.*, 1999).

In considering an appropriate dosage of β -glucan one must also consider the limitations set by the desire to maintain acceptable palatability and avoid the onset of negative side-effects. Of concern are gastrointestinal upsets including flatulence, cramping, bloating, loose stools and diarrhoea caused by higher levels of soluble fibre. It should be noted that 3g in one serve may cause gastrointestinal problems in many individuals. It is therefore recommended that β -glucan intake be spread across the day with the incorporation into various foods (Bell *et al.* 1999).

3.3 CHD and Fatty Acids

The quantity and degree of saturation of fat are important risk factors for cardiovascular disease. The National Heart Foundation of New Zealand Advisory Committee (White, 1999) advise at risk people to select foods that are low in saturated and trans-unsaturated fatty acids and to eat moderate amounts of monounsaturated and polyunsaturated fats to minimize the risk of CHD. The New Zealand Nutrition Taskforce also recommended that total fat contribute 30-33% or less of total energy (Matheson, 2002). For those at risk of heart disease low saturated fat should be emphasised even more.

The following sections will outline the common sources of the various types of fat, the scientific evidence of their benefit/harm in relation to CHD.

3.3.1. Saturated Fatty Acids

There is good evidence to support a correlation between saturated fatty acid (SFA) consumption and the development of CHD. The results of primary and secondary prevention trials have demonstrated adverse effects on cardiovascular clinical endpoints including non fatal myocardial infarction and fatal CHD from high intake of SFA (Allman-Farinelli, 1999). Saturated fatty acid consumption has been consistently shown to increase CHD risk in cohort, case control and descriptive studies (Allman-Farinelli, 1999). This relationship has been confirmed in various population groups. Thus, it is important that the overall make up of the new cereal bar is low in saturated fat.

3.3.2. Monounsaturated Fatty Acids

Monounsaturated fatty acids (MUFA) are abundant in the Mediterranean diet which has been associated with reduced risk of CHD. Foods rich in monounsaturated fats include olive oil, canola oil, almonds, macadamias, pistachios, hazelnuts and avocados.

Although there is little evidence of an independent effect of monounsaturated fatty acids on coronary endpoints, there is good evidence that replacement of SFAs with MUFAs lowers total and LDL cholesterol (Allman-Farinelli, 1999), an independent risk factor for heart disease. The effect of monounsaturated fatty acids on other risk factors is unclear.

3.3.3. Polyunsaturated Fatty Acids

There is good evidence that Polyunsaturated fatty acids (PUFAs) decrease risk of coronary events and deaths (Allman-Farinelli, 1999).

There are two types of polyunsaturated fats (PUFA) of interest in relation to CHD, omega-6 (*n-6*) and omega-3 (*n-3*) polyunsaturated fats. Omega-6 fatty acids (FAs) include linoleic acid (LA) and are derived from wholegrain cereals, nuts, and vegetables. Omega-3 PUFAs may be obtained from two sources, plants such as flaxseed which are high in alpha-linolenic acid (ALA), or fish, which are rich in docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA), with higher levels in oily fish.

Although there are no official recommended dietary intakes for omega-3 and omega-6 polyunsaturated fatty acids, The International Society for the Study of Fatty Acids and Lipids (ISSFAL) working group suggest adequate intakes of 0.65g/day (EPA + DHA), 2.22g/day (ALA) and 4.44g/day (LA) with an upper limit of 6.67g/day (Simopoulos *et al.*, 1999). The current omega-6 intake in Western countries is much higher than recommended. The Australian intake of omega-6 is estimated to be approximately 12g/day and current omega-3 intake is low (<1g/day) (Sinclair, 1993). Although diets vary slightly between the two countries, it is assumed that the New Zealand intake of omega-3 would be similar to the Australian intake.

Humans metabolise LA to a longer chain fatty acid called arachidonic acid (AA) using the same desaturation enzymes as used to convert alpha-linolenic acid (omega-3) to eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) (Simopoulos, 1991), hence there is competition between omega-3 and omega-6. Hence, ISSFAL recommend that the levels of omega-6 fatty acids should be reduced in favour of omega-3 fatty acids (Simopoulos *et al.*, 1999). It is therefore recommended that should PUFAs be added to the nutritional ingredient, omega-3 and not omega-6 fatty acids should be added. Therefore only omega-3 is reported in this review.

3.3.3.1. Omega-3

Omega-3 fatty acids are derived from plant and marine sources. It is important to distinguish between these two sources as they are structurally and functionally different. Omega-3 acts by reducing the concentration of plasma triglycerides (TG) and reduces the clotting of arteries. However, plant sources of *n-3* PUFAs do not lower TG levels to the same extent as marine *n-3* fatty acids (Allman-Farinelli, 1999).

Marine Source

Marine *n-3* PUFAs have been shown to lower fasting plasma TG by approximately 25-30%, increase LDL cholesterol concentrations by 5-10% and HDL concentrations by 1-3%, with no effect on total cholesterol with an average dose of 3-4g/day and maximum dose of 7g per day (Allman-Farinelli, 1999). Despite this, the FDA have refused to allow a health claim for *n-3* fatty acids in relation to CHD. It is argued that although recent diet intervention studies have shown beneficial effect in the diseased population, the effect in the general population has not been suitably shown (Lewis, 2000). In

addition, most of the studies have focused on the relationship between *n-3* PUFAs from fish and fish oils and CHD (Lewis, 2000). It is assumed that the beneficial effect is derived from the *n-3* rich oil. However, fish intake is not always distinguished from other factors associated with fish consumption (Wallingford and Yetley, 1991).

Plant Source

Since ALA can be converted to long chain *n-3* PUFA's it is suggested that this may be used as a functional ingredient instead of fish oils (Simopoulos, 1999). There is moderate evidence that α -linolenic acid (plant source of omega-3) reduces the risk of myocardial infarction and coronary heart deaths (Allman-Farinelli, 1999). ALA is transformed to EPA and DHA by desaturation and chain elongation enzymes in the liver. However, this conversion is slow and less efficient than direct incorporation of DHA and EPA from marine sources in the diet (Simopoulos, 1999). Therefore, a higher dosage would be required in order to achieve a similar effect (2g/day vs 0.65g/day). In addition, a certain portion of the population including vegans, premature infants, hypertensive individuals and some diabetics are unable to metabolise ALA to EPA and DHA (Simopoulos, 1991), therefore these people would not benefit from ALA addition.

Stearodonic acid has been shown to assist the conversion from ALA to EPA, and the addition of this would be recommended should ALA be used in the extruded ingredient or muesli bar. A commercial product (flaxseed + blackcurrant seed rich in stearodonic acid) is available from Functional Wholefoods (formerly Waihi Bush, NZ). The use of plant sources of omega-3 would be technically easier to incorporate into an ingredient due to the greater oxidative stability of ALA. However, as most of the studies have focused on marine *n-3*, it is unclear whether ALA would provide the same effect.

The FSANZ Food regulations specify that a higher level of ALA is required to make an omega-3 nutrient content claim than if EPA and DHA are used as the omega-3 source. There are no requirements for stearodonic acid addition. Details of the conditions required to make a nutrient content claim are outlined in chapter 4.

3.3.4. Trans fatty acids

A major concern that has surfaced recently is the concentration of trans fatty acids (TFAs) in the diet (Schaefer, 2002). Trans fatty acids are formed during the

hydrogenation of monounsaturated and polyunsaturated fatty acids (Schaefer, 2002). Major sources of trans fatty acids in the diet include processed foods, baked products and margarines rich in hydrogenated fat or oil. (Schaefer, 2002)

Results of cohort studies and case control studies suggest that CHD risk is increased with the consumption of trans fatty acids, particularly at high intakes (Allman-Farinelli, 1999). However, long term intervention studies are required to confirm the association. Trans fatty acids have been shown to increase total and LDL cholesterol more than non-hydrogenated vegetable oils (Allman-Farinelli, 1999). In addition, some studies suggest TFAs increase serum triglycerides and lower HDL cholesterol, while others found no significant effect (Allman-Farinelli, 1999).

Thus care must be taken that hydrogenation does not take place during extrusion if MUFAs or PUFAs are added.

3.4 CHD and Phytosterols

Plant sterols (phytosterols) and stanols (phytostanols) naturally occurring in wood pulp and vegetable oils, have been shown to lower total and LDL cholesterol (Nguyen, 1999). The effect has been demonstrated in various population groups including young and elderly men, premenopausal and postmenopausal women, children with and without familial hypocholesterolemia and patients with coronary heart disease and type II diabetes (Kris-Etherton *et al.*, 2002).

Source

Plant sterols have a similar structure to cholesterol (C-27); the major plant sterols in the diet are sitosterol (C-29), campesterol (C-28) and stigmasterol (C-29) (Nguyen, 1999). High contents of plant sterols can be found in edible oils, seeds and nuts (Weibrauch and Gardner, 1978, cited in Nguyen, 1999). Plant stanols are saturated derivatives of plant sterols. The most common plant stanol in the Western diet is sitostanol derived from wood pulp, tall oil and to a lesser extent soybean oil.

Dose

Most studies have shown plant stanols to be more efficient at lowering cholesterol than plant sterols, possibly attributed to the lower absorbability of plant stanols (Jones *et al.*, 1997 cited in Nguyen, 1999). In addition, the ester form of sitostanol is more efficient than the crystalline form (Vanhanen *et al.*, 1994 cited in Nguyen, 1999). Clinical studies on plant stanol esters have shown that a dosage of at least 1g/day to gain any drop in blood serum cholesterol levels and that intakes of 2-3g per day were needed to reduce serum cholesterol levels by 10-15% (Nguyen, 1999). However, research has shown that further reductions in cholesterol levels are not possible when 3 grams or more of sterols and stanols are consumed (Mensink and Plat, 1998 cited in Nguyen, 1999). Other reviews state reductions of LDL cholesterol of 9-10% to 20% are possible without any change in HDL-cholesterol and triglyceride levels (Cater N.B, 2000 and Lichtenstein and Deckelbaum, 2001 cited in Kris-Etherton *et al.*, 2002). The different results obtained in the various studies is difficult to reconcile due to the fact that the populations being studied more than likely differed in their background diet, baseline lipid levels and treatment duration (Nguyen, 1999).

The intake of phytosterols required for a significant cholesterol lowering benefit is 1-3g per day (de Deckere and Verschuren, 2000). Since a normal adult diet delivers approximately 100-300mg of plant sterols and 20-50mg plant stanols per day (Czubayko *et al.*, 1991 cited in Nguyen, 1999) phytosterol supplementation is required for a cholesterol lowering effect (de Deckere and Verschuren, 2000).

Mechanism

Plant sterols/stanols lower serum cholesterol by inhibiting the cholesterol absorption in the intestinal tract (Heinemann *et al.*, 1991 cited in Nguyen, 1999) by between 20 and 80%. Cholesterol absorbance is dependent on the length of the side chain, less cholesterol is absorbed as the side chain length increases due to increased hydrophobicity (Heinemann *et al.*, 1993 cited in Nguyen, 1999). The mechanism is not fully understood; however, it appears that plant sterols decrease the oil solubility of cholesterol and displace cholesterol from bile salt micelles, thus interfering with its absorption (Ikeda and Sugano, 1998 cited in Nguyen, 1999).

The absorption of phytosterols into the bloodstream is undesirable as they may initiate the development of atherosclerosis (Bhattacharyya and Connor, 1974 cited in Nguyen, 1999). The absorbance of plant sterols varies between the different forms; sitosterol has low absorbance (1.5-5%) (Kritchevsky, 1997 cited in Nguyen, 1999), whereas Lees and Lees, (1976 cited in Nguyen, 1999) suggested that campesterol which is much more absorbable should not be used therapeutically. Plant stanols have the advantage that they are virtually unabsorbable (Subbiah, 1973 cited in Nguyen, 1999). Between 0% and 3% of sitostanol is absorbed (Gylling *et al.*, 1999, Westrate and Meijer 1998 cited in Nguyen, 1999), and the absorption of campestanol is also low (Xu *et al.*, 1999 cited in Nguyen, 1999).

Although potentially effective at lowering serum cholesterol levels they may not be added to snack bars in NZ because the FSANZ food regulations expressly forbid their addition to such products, they may be added to fat based spreads only. However, in the US plant sterols may be added to other foods as well. The FDA has issued a heart health claim for the consumption of 4.5g plant sterol/stanol esters per day (Kris-Etherton *et al.*, 2002).

3.5 CHD and Soya

Benefit

The cholesterol lowering effect of soy and soy components is unclear. Human studies have shown variable results, some researchers have shown significant reductions in total and LDL-cholesterol, others moderate reductions and some have found little or no effect (Carroll, 1991). Overall, it appears that replacement of animal protein with soy protein may lower total and LDL cholesterol; this effect is greater in subjects with raised cholesterol.

Humans with raised cholesterol levels tend to be more responsive to the cholesterol lowering effect of soy than people with normal cholesterol levels (Carroll, 1991). Studies have been conducted involving partial or total replacement of animal protein with soy protein of varying purity. Cholesterol reductions of 8 to 16% have been found in a number of studies on hypocholesterolemic patients (Carroll, 1991) with diets composed of approximately 20% soy protein, with reductions of up to 20% (Sitori *et al.*,

1977, 1979, 1985; and Descovich *et al.*, 1980 cited in Carroll, 1991) or even 30% (Verillo *et al.*, 1985 cited in Carroll, 1991) reported in some instances. Meta-analyses have reported an average LDL-cholesterol reduction of 13% with doses of 47g/day of soy protein for hypercholesterolemic subjects (Anderson and Johnstone, 1995 cited in Kris-Etherton *et al.*, 2002). In contrast relatively little effect has been shown in subjects with normal cholesterol levels. Although a number of mechanisms have been proposed, it is unclear what components in soy protein are responsible for the cholesterol lowering effect (Carroll, 1991). In addition, more work is required to evaluate whether the effect is attributed to the removal of animal protein or to the addition of soy protein (Carroll, 1991).

Dose

The FDA has issued a health claim for the relationship between the consumption of 25g of soya protein per day and a reduced risk of heart disease (Brouns, 2000). To qualify for a health claim, a product must contain 7.5g of soy protein per serve. The typical consumption of soy in New Zealand is unknown, however there is relatively little soy protein in processed foods in New Zealand.

3.6 CHD and Folate

Folates reduce the risk of coronary heart disease by decreasing the level of the plasma amino acid homocysteine. High levels of homocysteine, i.e, greater than 14 $\mu\text{mol/L}$, is an independent risk factor for coronary heart disease (Hankley and Eikelbaum, 1999 cited in Hasselwander *et al.*, 2000; White, 1999). Although there is not yet evidence from intervention trials, there is sufficient evidence to suggest a causal relationship between high plasma homocysteine levels and coronary heart disease (Hasselwander *et al.*, 2000).

The term folate refers to both the naturally occurring reduced folates (e.g. 5-methyltetrahydrofolate (5-MTHF), 10-formyl-tetrahydrofolate (THF) and 5,10-methylene-THF) and synthesized folic acid. Dietary sources of folates include green leafy vegetables, oranges and liver. The more stable folic acid is used widely in vitamin supplements and food fortification. Synthetic folic acid is better absorbed (approximately 50% greater absorption) than natural folates (White, 1999).

A homocysteine increase of 5 μ mol/L (normal levels range from 5-15 μ mol/L) increases cardiovascular risk by 60-80% (Boushey *et al.*, 1995 cited in Hasselwander *et al.*, 2000). Intake of 0.4-5.0mg/day of folic acid lowers homocysteine by 25% (Boushey *et al.*, 1995 cited in Hasselwander *et al.*, 2000). Plasma homocysteine levels may be lowered by a further 7% with the addition of vitamin B12, but not vitamin B6 (Clarke, 1998 cited in Hasselwander *et al.*, 2000).

High intakes of folic acid may mask vitamin B12 deficiency, a condition that affects 10-15% of the over 65 years US population. To avoid correcting haematological signs of vitamin B12 deficiency, 5-MTHF can be used instead of folic acid. This form is also more effective in reducing homocysteine levels in the 5-15% of people with reduced methylenetetrahydrofolate reductase (MTHFR) activity (Hasselwander *et al.*, 2000). However, at present 5-MTHF is classed as a novel food and not permitted under ANZFA food law.

Although raised homocysteine is becoming well recognized as a risk factor for coronary heart disease, it only affects a small percentage of the population. Under the FSANZ regulations, folate may be added to breakfast cereals, dietary supplements and meal replacements only, and not standard cereal bars. The FDA has denied a health claim for folate and coronary heart disease due to a lack of evidence of benefit from human intervention trials. Hence folate should not be included in the extruded ingredient, but added to specific permitted applications to maximise the flexibility of ingredient usage.

3.7 Antioxidants

The National Heart Foundation of New Zealand has concluded that there is insufficient evidence to suggest that antioxidant vitamins (vitamin E, β -carotene and vitamin C) assist in the prevention of cardiovascular disease (White, 1999). Although high intakes of antioxidant vitamins have been linked to a lower incidence of CHD in some observational studies, results have been controversial when tested in different populations (White, 1999).

Vitamin E may protect against LDL cholesterol oxidation, however, two large randomized controlled trials have demonstrated that there is no clear benefit (White, 1999). Neither vitamin C nor β -carotene have been proven to be effective in coronary heart disease prevention, in fact supplemental β -carotene may increase the risk of myocardial infarction (White, 1999).

3.8 Extrusion and Nutrition

The intention of this research was to develop a functional extruded cereal ingredient that provided the desired health benefiting properties, in addition to meeting organoleptic properties that make it suitable for use in cereal bar products. The raw materials used in Functional Food products are often undesirable or unpalatable (Camire, 2001). Extrusion technology can be used to transform these raw ingredients into a useful product with desirable textural and taste characteristics. Food extrusion is a process in which food ingredients are forced to flow, under one or several conditions of mixing, heating and shear through a die that forms or puff-dries the ingredients (Rossen and Miller, 1973 cited in Riaz 2001). Extrusion is a high temperature, short time process, as it involves high temperatures (up to 190°C) but usually short residence times (typically 20-40 seconds).

Extrusion may improve the nutritional quality of some nutrients, for example dietary fibre may be increased during extrusion (Camire, 2001), whilst other nutrients may be retained or partially degraded, e.g. antioxidants. Anti-nutrient compounds may be reduced during extrusion processing to produce more nutritious and safer foods (Camire, 2001). In order to produce highly nutritional extruded products, the conditions must be carefully considered. Since expanded snack extrudates require relatively high temperatures, nutrients included in such an ingredient must withstand these conditions or better still be enhanced by such conditions. Nutrients that can be enhanced by extrusion or have a high level of retention are of greatest interest in this project.

The main aim of this initial extrusion review was to assess the practicality of extruding the heart benefit nutrients of interest (as identified earlier in this section). In particular, consideration was given to the effect of extrusion on the nutritional properties of each

nutrient reviewed and hence any implications on heart health benefit and any impact nutrient addition would have on product texture. This review did not attempt to relate nutrient retention to any one factor in extrusion processing, as it is acknowledged that there are many interrelated factors in extrusion (Björck and Asp, 1983). In addition, processing under different conditions, including the use of a different extruder may yield different results. Contradictory results found in the literature are presented.

3.8.1. Dietary Fibre

Although food labelling regulations require the labelling of total dietary fibre, it has been established that it is the soluble fibre fraction that is associated with a reduced risk of heart disease (Camire, 2001) due to its purported cholesterol lowering effect (Brown *et al.*, 1999). Therefore the possible enhancement in the extrusion process of total dietary fibre and soluble dietary fibre is of significant interest for nutritional labelling and heart health benefits respectively. This section briefly describes the effect of extrusion processing on dietary fibre content and solubility and attempts to relate the compositional properties to physiological effects.

3.8.1.1. Effect of Extrusion Processing on Dietary Fibre Content

The effect of extrusion processing on dietary fibre content is unclear (Camire *et al.* 1990; Camire and Flint, 1991; Gualberto *et al.*, 1997). Authors have shown extrusion processing to increase dietary fibre content, decrease fibre content, or cause no significant change in dietary fibre content depending on the materials and processing conditions used and the analytical method used to determine dietary fibre content. In addition, a number of researchers have shown a redistribution of the insoluble portion of dietary fibre to soluble fibre for a number of different fibre sources. Different results reported are summarised in Table 3.1 below.

Table 3.1: Effect of extrusion processing on total dietary fibre and soluble dietary fibre

<i>References</i>	<i>Extruded Materials</i>	<i>Extrusion Conditions</i>	<i>Change in TDF (%)</i>	<i>Change in SDF (%)</i>
Björck <i>et al.</i> (1984)	Wheat Flour	Least severe Most Severe	No change ↑ 22.5%	↑ 23.5% ↑ 123.5%
	Whole grain wheat	Least severe Most Severe	↑ 9.9% ↑ 8.3%	↑ 40% ↑ 65%
Camire and Flint (1991)	Oatmeal		↑ 13.8%	
Gaulberto <i>et al.</i> (1997)	Oat Bran	Low Med High	↑ 24.7% ↑ 25.5% ↑ 19.1%	↑ 58.2% ↑ 51.8% ↑ 32.7%
	Rice Bran	Low Med High	↓ 4.1% ↓ 4.7% ↓ 3.5%	↑ 29.5% ↑ 16.5% ↑ 0.5%
	Wheat Bran	Low Med High	↓ 3.1% ↓ 4.2% ↓ 4.0%	↓ 4.5% ↓ 10.9% ↓ 7.7%
Fornal <i>et al.</i> (1987)	Buckwheat / Barley Starch 50:50 Mixture	Standard extrusion conditions	↓ 40.5%	Not reported
	Buckwheat/ Barley/Corn starch		↓ 52.9%	Not reported
	Barley/Corn Starch		↓ 55.1%	Not reported
Kahlon <i>et al.</i> (1998)	Rice Bran	Low energy input High energy input	↓ 6.3% ↑ 3.3%	↓ 8.0% ↑ 12.0%
	Oat Bran	Low energy input High energy input	↓ 2.0% ↑ 13.3%	↓ 8.0% ↑ 8.0%
	Corn Bran	Low energy input High energy input	↓ 16.2% ↓ 17.7%	↑ 150% ↑ 50%
	Wheat Bran	Low energy input High energy input	↓ 10.9% ↓ 14.9%	↓ 26.3% ↓ 18.4%
Ralet <i>et al.</i> (1991)	Sugar Beet Pulp	Medium Intensity High Intensity	↑ 0.4% (no change) ↓ 6.9%	↑ 142.7% ↑ 181.6%
Artz <i>et al.</i> (1990)	Corn Fibre / Corn Starch blends	Response Surface design varying barrel temperature, screw speed and pH.	No significant changes	No significant changes
Varo <i>et al.</i> (1983)	Wholegrain Wheat Meal Wheat Flour	Normal Moderately Excessive	No significant changes	No significant changes

Increased Dietary Fibre Content

Extrusion processing has been shown to increase the total dietary fibre content in a range of fibre containing cereals including oat (Camire and Flint, 1991; Gaulberto *et al.*, 1997, Kahlon *et al.*, 1998), wheat (Björck *et al.*, 1984) and rice bran (Kahlon *et al.*, 1998) under certain processing conditions as summarised in Table 3.1 above. Whilst some authours (Björck *et al.*, 1984) suggest increases in dietary fibre tend to occur (to a greater extent) under more extreme processing conditions of high shear, temperature and pressure, the results summarised in Table 3.1 above do not show any clear trends based on processing severity. Increases in total dietary fibre content have been attributed to the formation of residual “resistant starch” (Björck *et al.*, 1984; Camire and Flint, 1991; and Theander and Westerlund, 1987) and the formation of Maillard reaction polymers (that are analysed as Klason lignin) (Theander and Westerlund, 1987).

Decreased Dietary Fibre Content

Decreases in dietary fibre content were found by several authours. The most significant decreases in dietary fibre were found by Fornal *et al.* (1987) for mixtures of buckwheat, barley and corn starch mixtures extruded under mild conditions (125°C). Decreases of 5.8% - 9.8% (dm) were observed which equates to a 40-55% reduction in fibre. The greatest decrease occurred in the cellulose and lignin (insoluble fibre) components, the author of these results assumed that thermal decomposition had occurred (Fornal *et al.*, 1987). Slight decreases in dietary fibre were observed by Gaulberto *et al.* (1997) for rice bran and wheat bran under low, medium and high extrusion conditions, Kahlon *et al.* (1998) for rice bran and oat bran under low energy extrusion conditions and corn bran and wheat bran under low and high energy conditions and by Ralet *et al.* (1991) for sugar beet pulp extruded under high intensity conditions.

No change in Dietary Fibre Content

A number of authors observed no changes in total dietary fibre contents for a variety of raw materials including wheat flour, corn (corn fibre, corn starch and corn meal), rice, oat, and wheat brans (Varo *et al.*, 1983; Artz *et al.*, 1990; Kahlon *et al.*, 1998; Camire and Flint, 1991; Björck *et al.*, 1984; Siljeström *et al.*, 1986). Artz *et al.* (1990) suggest that chemical or enzymatic pre-treatments may be required to modify fibre by extrusion processing.

3.8.1.2. Effect of Extrusion Processing on Dietary Fibre Solubility

Increased Solubility

A number of researchers have shown a redistribution of the insoluble portion of dietary fibre to soluble fibre for a number of different fibre sources including wheat flour and whole grain wheat (Björck *et al.*, 1984), oat bran (Gaulberto *et al.*, 1997; Kahlon *et al.*, 1998), rice bran (Gaulberto *et al.*, 1997; Kahlon *et al.*, 1998) and sugar beet pulp (Ralet *et al.*, 1991). Related references are summarized in Table 3.1 above

Some authors found solubilisation of dietary fibre is more pronounced under 'extreme' processing conditions (Björck *et al.*, 1984; Kahlon *et al.*, 1988 (some); Ralet *et al.*, 1991). Others found less solubilisation under extreme conditions (Gaulberto *et al.*, 1997).

No Change in Fibre Solubility

Other researchers have reported no change in dietary fibre solubility (Artz *et al.*, 1990; Varo *et al.*, 1983).

Factors affecting fibre content and solubility

There are a number of factors that may contribute to the differences in results obtained by various authors. These factors include:

1. Chemical Changes

A possible explanation for these differences may be found when analysing the chemistry involved in extrusion of dietary fibre. Fragments may be sheared off to form smaller molecules; these smaller molecules may be water soluble, hence increasing the SDF content. However, there is also the possibility that these molecules bond with others to form large insoluble complexes that may be analysed as lignin, (Camire, 2001) and therefore analysed as insoluble fibre under some methods.

2. Dietary Fibre Analyses

The analytical methodology used for the quantification of dietary fibre may also be responsible for the differences between studies that have been reported in the literature. Methods used to characterize fibre components vary greatly. Extrusion studies that use different methods to characterize dietary fibre often reach contradictory conclusions (Camire, 2000). In a study on extruded wheat Varo *et al.* (1983, cited in Björck and Asp, 1983) concluded that dietary fibre solubility is highly dependent on the method of determination. Different analytical methods include different components in their classification of total, soluble and insoluble dietary fibre due to an ongoing debate about the definition of dietary fibre. Dietary fibre is usually classified as polysaccharides plus lignin; however there is debate over whether “resistant starch” fractions should be included in the dietary fibre definition (Asp, 1987). Resistant starch is not absorbed in the small intestine and may function in a similar way to dietary fibre (Slavin *et al.*, 2000). The method of Englest and Cummings (1988, cited in Camire and Flint, 1991) may yield lower fibre values than other methods as they do not include enzyme resistant starch, lignin and other non-starch polysaccharides in their method for non-starch polysaccharide determination.

3. Compositional Differences in Raw Materials

The chemical composition of extruded products is dependent on the physical (particle size, form eg. Flour vs wholegrain) and chemical characteristics (moisture, fat and fibre content) of raw materials (Kahlon *et al.*,1998).

4. Differences in Processing Conditions

Another possible reason for the results inconsistency may be due to different extruders and process conditions adopted in different studies.

3.8.1.3. Effect of Extrusion Processing on Dietary Fibre Viscosity

Although dietary fibre viscosity is not an issue for purposes of food labelling, viscosity does affect the functionality. The viscosity of soluble fibre has been found to increase during extrusion; aqueous suspensions of extruded wheat, barley and oats were more viscous than the unprocessed grains (Wang and Klopfenstein, 1993). Increased viscosity has beneficial heart health implications since it may increase binding to bile acids, and

may decrease absorption of dietary fat and cholesterol via increased intestinal viscosity, the two proposed methods for cholesterol reduction (refer to section 3.2.1).

3.8.1.4. Health Significance

The reason for interest in the soluble fibre content is due to the heart health benefits they provide. However, it is unknown whether soluble fibre produced during the extrusion process provides the same benefits as naturally occurring soluble fibre (Camire, 2000). Camire (2000) suggests findings have been contradictory; however, animal feeding studies tend to match nutrition assay results. For example, extruded barley and oats which contained increased soluble fibre (and slightly increased β -glucans), fed to young rats lowered total serum and liver cholesterol levels (Camire, 2000).

3.8.1.5. Effect on Product Texture

Dietary fibre may function as a bulking agent, binder and suspending agent in extruded products. Fibre enrichment of extruded products may decrease product expansion, thus decreasing desirability of sensory properties. Water is trapped within the fibre matrix; this higher moisture content creates less expansion and thick cell walls. Thickness expansion decreased linearly from 700% expansion with no added bran to 100% expansion with 60% added bran in extruded flat bread (Campanella and Shah, 1997).

However, supplementary fibre may be used to a limited level to produce expanded snacks. For example, 50% carboxymethyl cellulose (CMC) can be extruded with cornmeal to produce an expanded snack with 17% dietary fibre. The fibre source used also has an impact on the expansion that can be achieved. Beet fibre, fruit fibre, pea fibre and soy fibre are good expanders with low lipid levels and high soluble fibre content (5-25%); Carboxymethyl cellulose (CMC), corn fibre and wheat fibre provide moderate expansion, but are low in soluble fibre content; oat fibre, oat bran and rice flour are poor expanders due to a high lipid content (Campanella and Shah, 1997).

3.8.1.6. Summary

In summary, the total dietary fibre (TDF) content and soluble dietary fibre (SDF) content can be altered by the extrusion process. Total and soluble fibre contents have been shown to increase, remain the same or in some cases decrease. There are a number of factors that are thought to contribute to these differences including; the composition

of raw materials, the type of extruder used and extrusion processing conditions and the method of dietary fibre analysis used for dietary fibre determination. An increase in total dietary fibre is beneficial from a general nutrition and food labelling perspective and an increase in soluble dietary fibre is beneficial for heart health due to its cholesterol lowering effect. Hence, experimental work needs to be conducted to evaluate the effect of extrusion on the dietary fibre content with local raw materials and extrusion equipment.

3.9 Lipids

Although overall high level of fat in the diet has been associated with increased CHD risk, monounsaturated and polyunsaturated fatty acids have been shown to provide a heart health benefit, therefore the extrusion stability of these lipids is of interest. Monounsaturated fats are more stable and resistant to oxidation than polyunsaturated fats, which is an important practical consideration for extrusion processing.

Only one study has been published on the stability of omega-3 in the extrusion process. Docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) were retained in chum salmon muscle (Suzuki *et al.*, 1988). However, it is suspected that the chum salmon muscle provided protection that would not be possible should omega-3 polyunsaturated fatty acids in the form of fish oil be included in the formulation of an extruded cereal ingredient. It is expected that these particular unsaturated lipids would undergo lipid oxidation at the high temperature and pressure typical in extrusion operation. The use of plant sources of *n-3* would be technically easier to incorporate into an ingredient due to the greater oxidative stability of ALA. However, as most of the studies have focused on marine *n-3*, it is unclear whether ALA would provide the same health effect. Stearidonic acid has been shown to assist the conversion from ALA to EPA, and the addition of this would be recommended should ALA be used in the extruded ingredient or muesli bar. A commercial product (flaxseed + blackcurrant seed rich in stearidonic acid) is available from Functional Wholefoods (formerly Waihi Bush, NZ). Tahoven *et al.* (1998) reported only slight changes in fatty acid profile including stearidonic acid in an dried blackcurrant press residue extruded at high temperatures (173-184°C), however, the degradation over time requires further study.

Oxidation is a major issue in extruded products, since in addition to high temperature and pressure, the formation of air cells in expanded products, leads to increased surface area for oxygen attack (Camire, 2001). The rate of oxidation increases in proportion to the exposed surface area (Nawar, 1996). Although oxidation does not occur in the brief residence time within the extruder, lipid oxidation may occur during storage (Camire, 2001). Also, screw wear results in high concentrations of transition metals (e.g. iron) (Camire, 2001); transition metals are effective pro-oxidants and catalyse oxidation reactions and increase the rate of oxidation even at low concentrations (0.1ppm) (Nawar, 1996). Semwal *et al.* (1994) found higher iron and peroxide values in extruded rice and dhal.

However to counter these factors, resistance to oxidation may be increased in the following ways:

1. The formation of starch –lipid complexes formed during extrusion,
2. Lipolytic enzymes and other enzymes that promote oxidation may be inactivated,
3. Packaging under nitrogen or under vacuum in opaque containers (Camire, 2001),
4. Maillard compounds formed within the extruder may act as antioxidants (Camire 2000).

Aorora and Camire (1994 cited in Camire, 2000) found that extruded potato peels had higher antioxidant activity than non extruded peels, and oatmeal cookies with added potato peels had lower peroxide values than control samples. However, most antioxidants are not heat stable which limits their usefulness in extruded products (Camire, 2001).

The other nutritional issue of concern is the formation of trans fatty acids (Camire, 2001), which may be favoured within the extruder. There is some evidence that trans fatty acids increase the risk of coronary heart disease (Allman-Farinelli, 1999). The beneficial effect of adding mono- or polyunsaturated fats to an extrusion may be negated by trans fatty acids being formed. However, Maga (1978 cited in Camire, 2001) found that extrusion of corn and soy resulted in only 1.5% trans fatty acids. Such low levels are not a major concern.

Effect on Product Texture

It is preferable for extruded products to contain less than 10 percent lipid. This is an ample amount to provide heart health benefits from polyunsaturated fats. Larger quantities of lipid reduce slip within the extruder barrel and prohibit expansion (Guy, 2001). High levels of fat may decrease expansion and increase the size of air bubbles. Decreased expansion is due to lipids forming complexes with amylose and thus starch gelatinisation is decreased (Campanella and Shah, 1997). Fats coat starch molecules and restrict the amount of water they absorb, leading to decreased water solubility and a smoother surface (Campanella and Shah, 1997).

3.10 Phytosterols

Very little has been published on the stability of plant sterols during extrusion processing. However, these monounsaturated compounds are very stable, much more stable than monounsaturated fats due to steric hindrance. Although under high temperature conditions in the presence of air (as experienced during extrusion) phytosterol oxidation does occur; in other extreme processes such as deep fat frying sterol oxidation products are formed in very small (ppm) quantities only (ANZFA, 2001a).

3.11 Soya

Soya protein has been shown to have cholesterol lowering properties (Brouns, 2000) and hence the extrusion stability of soya protein is of interest.

In extrusion, soy protein undergoes a process called “texturisation” where the proteins are plasticised and reoriented to form an open celled protein matrix (fibre like structure) in which insoluble carbohydrates are dispersed. The main chemical change that protein undergoes during the extrusion process is protein denaturation (Camire, 2000). Denaturation improves protein digestibility; the extent of denaturation is greatest under conditions of high shear (Della Valle *et al.*, 1994 cited in Camire, 2001) although mass temperature and moisture content are also important factors.

Protein nutritional quality may be decreased by maillard reactions and oxidation, resulting in the loss of essential amino acids, and cross linking of proteins (formation of dipeptide bonds) may decrease digestability (Asp, 1987). Many other factors affect protein digestability including exposure of enzyme susceptible sites (increases digestability) and formation of dipeptide bonds (decreases digestability) (Camire, 2000). Maillard reactions are favoured during extrusion and reducing sugars can react with lysine, and thus lower the nutritional value of protein. (Camire, 2000).

In rat studies, extrusion texturisation of soy isolate did not reduce its effect on serum cholesterol levels, excretion of cholesterol, or protein nutrition compared to non extruded soy (Fukui *et al.*, 1993 cited in Camire 2001). Thus, it appears that the heart health benefits are retained during extrusion.

Effect on Product Texture

Although soya beans are difficult to extrude to well defined products, due to a very high oil content (approx 20%) (Frame, 1994), soy protein and soy isoflavones should not create problems. Addition of soy protein to the extruded ingredient formulation may result in a product with less expansion, increased crunchiness, increased firmness and greater water resistance (Campanella and Shah, 1997). Soy protein is easily extruded as there is only a small volume of insoluble carbohydrate to be dispersed in the open celled protein matrix (Campanella and Shah, 1997). No information has been published on the effect of concentrated soy isoflavones on the product texture of extruded products, however, as a minor component it is not expected to have significant effects.

3.12 Folate

Folic acid is of interest, due to the potential heart health benefit it provides through serum homocysteine modulation. Lorenz and Jansen (1980, cited in Camire, 2001) observed less than 10% loss of folic acid in naturally occurring corn soy blends extruded at 171°C using a single-screw extruder. Frame (1994) suggests losses of vitamin B12 of 1-40%. The retention of folic acid and B vitamins added to crisp bread as a vitamin pre-mix was investigated by Millauer *et al.* (1984, cited in Cheftel, 1986), folic acid retention of 35-45% and 56% were found on laboratory and commercial scale

Werner Pfeleiderer extruders respectively. Therefore, the loss expected would be 10-65% depending on extrusion conditions.

3.13 Vitamin E

Vitamin E is of interest as it may provide heart health benefits via protection against LDL cholesterol oxidation. Vitamin E and related tocopherols are highly unstable compounds and are all degraded by heat and oxygen. Wennermark (1993 cited in Camire, 2000) found that less than 20 percent of naturally occurring vitamin E was retained in extruded wheat flour. Vitamin losses increased with increasing barrel temperature (and low moisture content). Therefore, application post-extrusion is recommended.

Frame (1994) suggests several options to overcome losses during extrusion;

1. The use of overage to compensate for processing and storage losses
2. The use of encapsulated forms with improved heat stability
3. Addition of vitamins post extrusion e.g. Incorporated into fat coating and sprayed on to extrudates

Vitamin E may be easily incorporated into a bar formulation and the storage stability better preserved by using encapsulated forms post extrusion.

3.14 Conclusions and Recommendations

A healthy diet may reduce a person's risk of CHD by reducing serum cholesterol, triglyceride levels, homocysteine levels and the incidence of diabetes mellitus. The ingredients identified as providing a heart health benefit and deemed to be suitable for inclusion in a muesli bar through a review of the available literature were; dietary fibre, mono- and polyunsaturated fatty acids, phytosterols, soya, and folate. There was insufficient evidence to suggest antioxidants reduced the risk of CHD.

The impact of extrusion processing on the nutritional quality and texture of these ingredients was reviewed. Extrusion is a high temperature, high shear process.

Extrusion processing may be used as a method of improving the palatability, and textural acceptability of functional ingredients so that they can be incorporated into cereal bars and other products in the form of an expanded nugget. Extrusion may also improve the nutritional quality of certain nutrients.

Dietary Fibre

Soluble dietary fibre was found to decrease total and LDL cholesterol. Manageable daily doses of soluble fibre of around 5-10g (total daily intake) decreased total cholesterol by approximately 5-10% which equates to a 10-20% decreased risk of CHD. Decreases in cholesterol were seen in both the normal and hypocholesterolemic populations. The source of fibre was not related to the effect, thus oat β -glucan was selected as the best option due to higher consumer awareness, health claims in the US and the low cost of oat ingredients. Extrusion processing may have a positive nutritional effect on dietary fibre increasing total and/or soluble dietary fibre content. In addition, the viscosity of soluble fibre may be increased by extrusion, enhancing the cholesterol lowering properties. However, high levels of fibre were found to limit product expansion. Although current New Zealand total dietary fibre intakes are below recommendations, soluble fibre intakes are approx. 10g per day, enough to provide a cholesterol lowering benefit.

Fatty Acids

Saturated fats are associated with CHD. Replacement of saturated fats with monounsaturated fats lower total and LDL cholesterol. Omega-3 polyunsaturated fats have been shown to lower triglyceride levels and clotting of arteries and hence reduce the risk of CHD. The marine source of omega-3 (DHA+ EPA) is more efficient at lowering triglyceride levels than the plant source of omega-3 (ALA) which first requires conversion to EPA + DHA. An adequate daily intake of omega-3 is 0.65g/day (DHA+ EPA) or 2.22g/day (ALA). Assuming New Zealand omega-3 intake is similar to the Australian intake of omega-3, current New Zealand intake is well below this level (Sinclair, 1993). High levels of fat may decrease extrusion product expansion, thus having an adverse effect on product texture. In addition, extrusion conditions favour lipid oxidation and the formation of trans fatty acids, which may negate heart health benefits provide by mono- or polyunsaturated fat addition. It is therefore advised that

unsaturated fats are preferably included in the final application or spray coated post extrusion and suitably packaged.

Phytosterols

A dosage of 2-3g of phytosterols per day lowers LDL cholesterol by between 10 and 20% in various population groups without a commensurate change in HDL cholesterol or triglyceride levels. At least 1g per day is required for a cholesterol lowering effect. The normal diet delivers considerably less than this amount. But FSANZ food regulations currently permit the addition of plant sterols to fat based spreads only.

Plant sterols are reasonably stable, more so than monounsaturated fats. However, it is expected that a small amount of lipid oxidation will occur during extrusion processing. Phytosterols are not expected to have any adverse effects on the textural properties of extruded products.

Soya

High doses (47g/d) of soya protein have been shown to reduce LDL cholesterol by an average of 13% in hypocholesterolemic patients, however little effect has been shown in the normal population. The FDA has permitted a heart health claim for products containing 7.5g of soy protein per serve (25g per day). The typical consumption of soy in New Zealand is unknown, but would be considerably less than this amount. The cholesterol lowering properties of soy protein are thought to be retained during extrusion processing, however soy protein decreases expansion. Therefore, extrusion of soy protein is a viable option.

Folate

Folic acid may reduce the risk of heart disease in the 1-2% of the population with high homocysteine levels through homocysteine modulation. The level of folate required for heart health benefit is approximately 400-500µg and the current New Zealand intake is 242µg, therefore supplementation may be beneficial. Folic acid is currently permitted in breakfast cereals or dietary supplements/meal replacements, not in snack bars under the FSANZ regulations.

Folic acid is heat sensitive and as a consequence potentially large losses could occur during extrusion. Naturally occurring folate appears to be more stable. Folate is a minor ingredient and is not expected to have an effect on product texture.

It would be more practicable to add folate to a bar product or to spray it onto the bar post extrusion for a breakfast inclusion.

Antioxidant Vitamins

There is insufficient evidence to suggest that antioxidants reduce the risk of CHD through reduction of cholesterol oxidation. Vitamin E has the strongest evidence. Vitamin E is highly unstable and is degraded during the extrusion process. Post extrusion addition of vitamin E is recommended and the use of encapsulated forms to improve storage stability.

Table 3.2: Summary of Heart Health Benefits and Extrusion Processing Stability of Nutrients Investigated

	<i>Risk Factor</i>	<i>Size of Benefit</i>	<i>Strength of Evidence</i>	<i>Population Group</i>	<i>Current NZ Intakes</i>	<i>Extrusion Stability</i>
Dietary Fibre	Cholesterol	Small	High	All	Low	Good
Fats Monounsaturated Polyunsaturated	Cholesterol Triglycerides	Moderate	High High	All Population with raised triglyceride levels	Low	Low Very Low
Phytosterols	Cholesterol	Large	High	All	Low	Moderate
Soya	Cholesterol	Moderate	High	Hypocholesterolemic only	Low	Good
Folate	Homocysteine	Large	Moderate	Small percentage of population with raised homocysteine	Most people meet RDI, but higher levels benefit	Low
Antioxidants	LDL cholesterol oxidation	Small	Low	All	Most people meet RDI, but higher levels benefit	Low

Dietary fibre and soy protein are the most practical nutrients to include in an extruded ingredient, both in terms of potential health benefit and in relation to stability under extrusion. Phytosterols may also be suitable for extrusion, but their use in cereal bars is not permitted under the FSANZ regulations. Lipids, folic acid and antioxidants would

be degraded during the extrusion operation and therefore should be included in post extrusion processes if desired.

4. REGULATIONS REVIEW

4.1 Regulation of Claims

The development and marketing of functional food products requires a new area of understanding for food manufacturers in terms of food regulations, particularly legislation in relation to nutrition and health claims as these can become major constraints in any new product development. The development of this ingredient for functional foods requires consideration of the food regulations in the major target markets, i.e. New Zealand and the US. In addition, the New Zealand Heart Foundation Heart Tick guidelines are important to consider, as it is desirable for products containing the ingredient to be endorsed under the Tick program.

Functional foods are often described as being the grey area between conventional food products and pharmaceutical drugs. The lack of a separate regulatory framework for functional foods in most parts of the world means that functional foods are generally treated as conventional foods and regulated under food law, with the exception of Japan which has a separate framework for functional foods. Some countries also have a separate framework for dietary supplements, food products may fall into this category if they meet certain criteria. However, it should be noted that the regulations applicable to each country dictate whether or not functional food products are permitted in the market. At present, there are restrictions on novel food products; regulatory bodies conduct a thorough and lengthy safety evaluation in the approval process for new ingredients.

In addition to the regulatory restrictions placed on functional foods, the lack of allowable health claims in some countries presents an impediment to the effective marketing of functional foods. Food manufacturers rely on the use of health claims (if permitted) and nutrition content statements on pack and in advertising to express the nutritional and health benefits of their products, which may provide competitive advantage. The lack of permitted health claims is often described as a reason for holding back the food industry from investing in functional foods development. However,

consumer studies show that a nutrient content statement may be as effective, provided the associated health benefit is well known (Levy *et al.*, 1997) as discussed in chapter 5.

However, before discussing the status of health claims in target markets, it is important to define how the nutrient information is presented and the types of claims permitted.

4.2 Nutrient Information and Health Claims

The constituents and nutritional content of food products are described on food packages in several ways, these include; an ingredient list, nutrition information panel, nutrient or health claims and a product description.

4.2.1. Ingredient List

In most countries the ingredients in a food product must be declared in descending order of content. Some countries (including NZ, Australia, and the UK) require percentage labelling of characterizing ingredients.

4.2.2. Nutrient Information

Nutrient information is compulsory in some countries and voluntary in others. The nutrient information is generally presented in the form of a Nutrition Information Panel, and includes the declaration of macronutrients and in some cases micronutrients. The information may be stated on a per serve basis or per 100g, depending on the country's regulations. Often the use of nutrition or health claims requires additional nutritional information to be declared.

4.2.3. Claims

4.2.3.1. Nutrient Content Claim

A nutrient content claim makes a statement about the presence (or absence) and amount of a certain nutrient without reference to the physiological role of the nutrient or health benefit. Examples of nutrient content claims include “good source of calcium”, “low fat”, “high fibre”. Nutrient content claims rely on consumer knowledge and desire for products containing high or low levels of those nutrients. A nutrient content claim may trigger the need to include information on the nutrition panel that was otherwise

voluntary. (E.g. in NZ a “good source of fibre” claim requires a declaration of the quantity of fibre per serve and per 100g to be included in the nutrition panel).

4.2.3.2. Structure-Function Claim

A structure function claim is a claim on a package which expresses the physiological role of a certain nutrient, such as “calcium aids in the growth and maintenance of bones”. Although the benefit in terms of disease prevention must not be stated, it may be inferred. A structure-function claim usually triggers the declaration of additional nutrient information.

4.2.3.3. Health Claim

A health claim describes a link between the nutrient, food component or food product and a disease state. Health claims may be classified as generic, commodity or ingredient specific, or product specific. Generic claims relate a nutrient to a diseased state e.g. “Diets high in soluble fibre and low in saturated fat may reduce the risk of Coronary Heart Disease”; commodity claims describe claims for ingredients, such claims allowed in the US include claims for oat bran and oatmeal, and psyllium. A product specific claim would state that a particular product has a protective effect against disease. For such a claim the product itself (rather than the ingredients or nutrients it contains) must have been shown to provide a benefit, and the product is usually assessed for efficacy and toxicity in the same way as drugs.

4.2 Regulatory Status of selected countries

The regulatory status in relation to health claims in NZ/Australia and the USA is briefly outlined below. Nice and Natural consider these countries to be the key target markets.

4.2.4. New Zealand and Australia

Food Regulations

Food labelling in New Zealand and Australia is regulated by the Joint Food Standards Code, Food Safety Australia New Zealand (FSANZ). In addition, in New Zealand foods may be manufactured under the New Zealand Dietary Supplements Act (ANZFA,

1995), however the long term future of these regulations is unknown. For the purpose of this project the FSANZ regulations shall be used.

Structure-function claims and nutrient content claims are allowed and frequently used. The use of these claims is regulated by FSANZ and by the Nutrition Code of Practice (ANZFA, 1995). The FSANZ food regulations must be adhered to; regulations contained in these regulations supersede the Nutrition Code of Practice. Claims for only a few nutrients are included in the Food Standards Code, the remainder are covered by the Nutrition Code of Practice which is a set of industry guidelines and compliance is voluntary i.e. manufacturer's responsibility.

Under the FSANZ regulations health claims are not currently permitted with the exception of folate in relation to the reduction in the incidence of neural tube defects. A health claims framework is under development, however this process is expected to take 5-7 years before the system is fully operational. Until then, claims that contain reference to disease or physiological condition; and claims that give advice of a medical nature are not permitted. Despite this, a growing number of products are carrying borderline health claims and making claims such as 'healthy'. For example, Burgen Oat bran and Honey Bread states "For Your Heart" on the package.

4.2.5. USA

Food Regulations

In the United States health claim regulations have been established through amendments to the Federal Food Drug and Cosmetic Act. These amendments include The Nutrition Labelling and Education Act (NLEA) of 1990 and the Food and Drug Modernisation Act (FDAMA) of 1997. Applications for new health claims may be approved if the FDA considers they are supported by valid and substantial scientific evidence, however this involves a lengthy approval process.

At present 13 health claims are permitted, the wording for claims is prescriptive and foods must meet a number of criteria in terms of composition, not only of 'claimed' nutrient but also other nutrients, such as fat content. The following are several examples of nutrient – disease relationships relevant to heart disease, that are supported by the FDA, and for which claims can be made;

- Sodium and hypertension
- Low fat foods and heart disease
- Fibre containing foods and heart disease
- Soluble fibres from psyllium, oat bran or oat meal and reduced risk of heart disease
- Soya and heart disease

The following is an example of a model claim;

“Soluble fiber from foods such as oat bran (and, if desired, the name of food product), as part of a diet low in saturated fat and cholesterol, may reduce the risk of heart disease. A serving of [name of food] supplies _____ grams of the 3g of soluble fibre from oats necessary per day to have this effect.” The Food and Drug Administration (FDA) regulate claims used on food products and supporting literature, whilst the Federal Trade Agency handles advertising claims.

Dietary Supplements

Purified preparations may be classified as dietary supplements. Under U.S. dietary supplement regulations only nutrient content and structure function claims are permitted, no health claims are allowed. Any purified product for which a health claim is made is considered a drug.

4.3 Relevant Claims permitted in New Zealand and US Market

Table 4.1 on the following page summarises the relevant health claims and nutrition content claims that can be made in the New Zealand and Australian markets and the US market for each heart benefit nutrient of interest. The conditions that need to be met to make the claims are also outlined. The US market has been included in addition to New Zealand as this has been identified as the market with greatest potential and therefore of most interest to Nice and Natural Ltd.

Table 4.1: Summary of relevant Health and Nutrition Content Claims in NZ and US Markets

<i>Ingredient</i>	<i>NZ /Australia</i>	<i>USA</i>
Oat Fibre	No health claim Source of Fibre = 1.5g/serve Good Source of Fibre =3g/serve Excellent source = 6g/serve	Heart health claim 0.75g beta-glucan per serve Low fat, saturated fat and cholesterol
Psyllium	No health claim Source of Fibre = 1.5g/serve Good Source of Fibre =3g/serve Excellent source = 6g/serve	Heart health claim 1.7g soluble fibre per reference amount (7g soluble fibre per day, 10.2g psyllium husk) Low fat, saturated fat and cholesterol.
Fat	No health claim Low Fat <3g fat Low Saturated Fat % Fat Free	Low fat <3g fat <30% calories from fat Low saturated fat <1g saturated fat <15% from saturated fat
Omega-3	No health claim Nutrient Content Claim "Source" if Saturated FA<28% total FA <5g/100g saturated FA 200mg ALA or 30mg EPA + DHA per serve "Good Source" if >60g EPA + DHA per serve	No claim permitted on conventional products May be listed outside N.I.P
Soy Protein	No health claim Protein content labelled in N.I.P High protein = approx. 15g	Heart Health Claim >6.25g per amt reference food Meet requirements for low fat, low saturated fat and low cholesterol food. (Recommend 25g per day)
Plant Sterols	Permitted in fat spreads only	Heart Health Claim 1.7g plant stanol esters per serve (snack bars permitted) Meet regulations for 'low saturated fat' and 'low cholesterol' food.
Low Sodium	Claim "low sodium" <120mg per 100g food Must state sodium and potassium content on NIP	No sodium: <5mg/serve Very low sodium: <35mg/serve Low sodium: <140mg/serve
Low cholesterol	"Low cholesterol" <20mg cholesterol/100g Cholesterol free <3g/100g Meet conditions for low fat claim or FA <20%sat and >40%cis-polyunsaturated or cis-monounsaturated FA. State saturated, trans, poly- and monounsaturated fatty acids	Low cholesterol <20mg cholesterol / ref amount <13g total fat <2g saturated fat Cholesterol free <2mg cholesterol <13g total fat <2g saturated fat
Vitamin E	Fortification allowed for formulated dietary supplements, sports foods or formulated meal replacements.	
Low sugar	Sugar free <0.2g/100g Low sugar <5g/100g	Sugar free <0.5g sugar Reduced sugar – 25% less than reference

Table 4.1 above highlights a number of differences between the regulations in New Zealand and Australia and the regulations in the US.

In the US, heart health claims can be made for oat fibre, psyllium, soy protein and plant sterols (provided the dose and overall nutrient values of the product meet the conditions required to make that health claim). Whereas, in New Zealand and Australia, heart health claims are not allowed, and only nutrient content claims (or structure function claims)

can be made in relation to fibre / protein etc. In the case of plant sterols, a structure-function claim can be made in New Zealand and Australia, however the addition of plant sterols is limited to margarine spreads.

Similar claims (nutrient content claims) can be made for fat, sodium, low cholesterol and sugar in New Zealand / Australia and the US, however the conditions of making such claims vary slightly between the American and the New Zealand / Australia regulations.

Omega-3 nutrient content claims may be made in New Zealand/ Australia, whereas no claim is permitted in the US.

Due to the large number of differences in terms of the claims that can be made as well as other differences in labelling requirements between the US and New Zealand / Australia, separate packaging would be required for products that are sold in these respective countries.

The formulation of these products may also differ, depending on (1) desired nutrient addition and whether those nutrients are permitted in cereal bars in all countries eg. it may be desirable to add plant sterols to bars sold in the US, whereas bars sold in New Zealand and Australia are not allowed to contain plant sterols; (2) the ability to market the benefits of certain nutrients and hence whether competitive market advantage may be obtained through addition of those nutrients. For instance, if psyllium or oat beta-glucan were added to a cereal bar, in New Zealand or Australia the claim would relate only to a good source of dietary fibre, thus if the heart health benefits of these fibres is not known by consumers, they may not provide any advantage over adding cheaper sources of dietary fibre; (3) consumer taste preferences in the country that the product is being sold ie. A popular flavour in the US may be undesirable to New Zealand or Australian consumers. Therefore, different flavours may be formulated for the different markets.

4.4 National Heart Foundation Guidelines

The National Heart Foundation of New Zealand endorses products under their 'Pick the Tick' program. This is a separate issue to the New Zealand food regulations. However, it is perceived by the consumer (refer to chapter 5) as a valuable "claim" and hence its inclusion in this section.

The Heart Foundation will endorse products provided they meet a number of criteria that have been set for the specific product category. The current criteria for cereal and fruit bars are as follows:

Fat: 5g/100g or less (Products with a fat level of between 5% and 10% will also be approved if the saturated fatty acids are 20% or less of total fatty acids.)

Sodium: 350mg/100g or less

Added sugar: 15g/100g or less

Dietary fibre: 3g/100g or more

It should be noted that these guidelines are currently under review and therefore subject to change within the next year. These changes are likely to refocus attention to the avoidance of saturated fat (rather than total fat) and possibly the inclusion of a trans fat guideline. An energy criteria is likely to be introduced to control the total fat intake in addition to sugar intake. The added sugar criterion is likely to be abolished. Sodium and dietary fibre guidelines are likely to remain (Monroe, Personal Communication).

4.5 Summary and Conclusions

Regulations relating to both content and claims will constrain the formulation of a functional extruded ingredient. Therefore, regulations in the target markets need to be taken into account. All ingredients identified as of interest in this research, ie. with heart health benefits, are permitted for use in cereal bars in New Zealand, Australia and the US except for plant sterols, which are permitted in the US only. Therefore, unless plant sterols are added, the same ingredient could be used in these different markets.

However, the labelling legislation and claims that can be made in each country is different and different products or labelling may be required.

The lack of permitted health claims in New Zealand and Australia may be prohibitive in the marketing of Functional Foods products. Claims in these markets are restricted to nutrient content claims eg. Good source of dietary fibre. However, for products meeting the criteria set by the National Heart Foundation, the heart tick may be used on packaging and this has been shown to be perceived by consumers as a useful “claim”. Therefore, it is recommended that bars are formulated to obtain the Heart Tick and the extruded ingredient should contribute towards meeting the Heart Tick requirements.

The US permits a number of health claims under its legislation for conventional foods. Heart health claims can be made for oat fibre, psyllium, soy protein and plant sterols. These claims are prescriptive and are subject to meeting the required dose and nutrition content. It is recommended that bars sold in the US utilise one or more of these ingredients and are formulated to be able to make a health claim.

5. CONSUMER RESEARCH

A review of the functional foods marketplace revealed that the success of functional food products has been variable. Product success is dependent on the product design meeting consumer needs and the product being appropriately positioned and communicated. Refer to chapter 2 for further information. This reinforces the importance of conducting consumer research to determine consumer needs. The Health Belief Model was used to assist in identifying factors for investigation.

5.1 Consumer Acceptance of Functional Foods

The commercial success of a snack bar product that provides heart health benefits is dependent on consumers' willingness to purchase such a product. The Health Belief Model is a theoretical model that has been frequently applied to nutritional intervention studies (Krummel *et al.*, 2002). This model has been used previously to investigate perceptions about the prevention of heart disease and behavioural change (Krummel *et al.*, 2002). In the current study the model has been used to identify factors that could assist in predicting consumers' willingness to purchase a snack bar with heart health benefits based on health motivation.

According to the Health Belief Model, consumers' willingness to purchase a snack bar product with health benefits (readiness to act) is dependent on their perceived susceptibility of developing a heart condition, the perceived severity of having a heart attack, a belief that consuming a snack bar (with heart benefit ingredients) will reduce the risk of developing a heart condition (perceived benefit). The perceived benefit may be influenced by the presence of endorsements and the credibility of educational and promotional messages. A muesli bar must be considered an appropriate and desirable food to provide heart health benefits, and must deliver on good taste, convenience, affordability and all other characteristics desired in a muesli bar (absence of barriers). Cues to action such as nutrient content claims, endorsements, educational and advertising material would assist in transforming willingness to the action of purchase.

A literature review was conducted to find consumer studies that illustrate the factors identified by the health belief model and identify areas that required further investigation. This model has been used as a framework to identify issues for investigation. However, this study was not intended to test the appropriateness of the health belief model. Although the health belief model can be applied to the design of change strategies and promotional messages to encourage people to make decisions, positive health marketing (life marketing) has proven to be more successful than focussing on disease severity and susceptibility (death marketing) (Heasman and Mellentin, 2002).

5.1.1. Perceived Susceptibility

In a study conducted by Worsely and Scott (2000) about Australian and New Zealand consumers' food and health concerns (and influence of socio-demographic factors and interrelationships between concerns) it was found that the relationship between food and disease (heart disease and cancer) was considered to be less important than a number of food safety issues, as well as some regulatory, ecological and equity issues. It is thought that the effect of diet on disease may become more important in future, but at the moment concerns are based on the desire for personal safety and well being. (Worsely and Scott, 2000).

In a US study, women aged over 60 years rated the risk of women developing heart disease greater than breast, lung and colon cancer (Wilcox and Stefanick, 1999), yet 44% of women thought it was unlikely they would have a heart attack in their lifetime. (Legato *et al.*, 1997 cited in Wilcox and Stefanick, 1999). Personal risk was often underestimated compared to general risk. A known family history of heart disease under the age of 65 years was associated with a greater perceived risk (Wilcox and Stefanick, 1999). Wiseman (1995) also found that personal risk was rated lower than the general risk.

5.1.2. Perceived Severity

Ischaemic heart disease was the second highest cause of death of New Zealanders in 1998 (6203 deaths) (NZHIS, 2003). Wiseman (1995) found that heart disease was perceived to be a serious problem for New Zealanders.

5.1.3. Perceived Benefit

General Practitioners often prescribe dietary changes to those people who have had a heart attack and even to those people who are at risk of heart attacks because their cholesterol readings may be high. However, it appears that people who have had heart attacks are more willing to change their diet than those who are at risk - the fear of dying is a very powerful motivation for dietary change and is more powerfully felt in those who have had a heart attack than those people at risk.

The perceived benefit is dependent on whether consumers consider diet to contribute to heart disease risk. A study conducted on cardiac patients in the US showed that most patients considered diet to be important and 67% believed poor diet had been one of the reasons for their attack (Plous *et al.*, 1995). However, a study conducted in 5 European countries indicated an attitude of indifference towards heart disease (Shepherd, 1998) despite a reasonable knowledge of cardiac risk, even among participants who had suffered a myocardial infarction. Often consumers have knowledge specific to health problems that they or family member may have (Patterson *et al.*, 2001). No information is available that shows how much greater nutritional awareness is among New Zealand consumers who have had heart problems or are conscious of heart health.

Consumer knowledge about foods and nutrients in relation to heart health is important in determining the perceived benefit of a product containing such nutrients. A postal questionnaire with 853 respondents (mailed out to 1500 people) from throughout New Zealand conducted in 1991 into "The beliefs about food components, foods, fat and heart disease in New Zealand" (Wiseman, 1994) showed that 93% of respondents thought that dietary fibre should be increased to reduce the risk of heart disease, the majority of consumers believed that reducing fat intake (91% of respondents), saturated fat intake (80% of respondents), salt (84% of consumers), sugar (66% of respondents), and intake of preservatives (61% of respondents) was important in reducing the risk of heart disease. Over 60% of respondents thought that more protein should be eaten and thirty eight percent of respondents thought that the consumption of fewer starchy carbohydrates would reduce the risk of heart disease.

However, the study identified confusion between “foods high in fat” and “fattening” foods, with sugar considered high in fat by over a third of respondents. In addition, consumers’ views of foods to avoid in order to reduce the risk of heart disease did not always relate to the fat content.

A study commissioned by ANZFA (Patterson *et al.*, 2001) on issues related to food labelling showed that New Zealand consumers have a superficial understanding of protein, energy, total and saturated fats and sodium. Some participants were aware of other minerals such as potassium, and vitamins such as folate, niacin and riboflavin. Use of the term 'sugar' on the label was not so well understood. Health conscious participants understood that there were naturally occurring and added sugars. However, the majority were confused by the different sugar related terms (sugar, added sugar, total sugar, natural sugars).

Little is known about New Zealand consumers’ awareness and knowledge of other beneficial nutrient components such as soluble fibre, omega-3 fatty acids, plant sterols, soya protein, folate and antioxidants.

5.1.4. Barriers

Perceived barriers are the practical and physiological barriers to eating a muesli bar with cholesterol lowering properties. The first barrier is reaching the primary target market (people with high cholesterol or concerned about high cholesterol) with such a product. The age groups most affected by high cholesterol are not as likely to eat muesli bars on a regular basis. Younger consumers, particularly females are more likely to consume muesli bars as seen by higher consumption of this age group in the National Nutrition Survey (Russell *et al.*, 1999). It is expected that consumers who do not currently eat muesli bars are less likely to buy muesli bars with cholesterol lowering properties, unless significant consumer education is undertaken.

Successful consumer education is dependent on the support of the National Heart Foundation, dieticians and family physicians since advertising is considered a reliable source of nutrition information by very few consumers. Gaining support of such nutrition experts may be a potential barrier if the product is not intrinsically healthy. In a

US focus group study physicians objected to recommending fortified snack foods since this endorses poor dietary behaviour (Schmidt *et al.*, 1998). Dieticians at the National Heart Foundation also prefer to promote whole foods and a balanced diet rather than individual nutrients (Roberts, Personal Communication, 2002).

US consumers also have expressed mixed views towards fortified snack foods. Some consumers were concerned about the high fat content of such products, whilst other consumers viewed fortified snack foods positively since the food would be eaten regardless of health benefits. (Schmidt *et al.*, 1998). Perceived barriers are the practical and physiological barriers to eating a muesli bar with cholesterol lowering properties. The first barrier is reaching the primary target market (people with high cholesterol or concerned about high cholesterol) with such a product. The age groups most affected by high cholesterol are not as likely to eat muesli bars on a regular basis. Younger consumers, particularly females are more likely to consume muesli bars as seen by higher consumption of this product by this age group in the National Nutrition Survey (Russell *et al.*, 1999). It is expected that consumers who do not currently eat muesli bars are less likely to buy muesli bars with cholesterol lowering properties, unless significant consumer education is undertaken.

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5.1.5. Cues to Action

Advertising, promotions, on-pack claims and endorsements may assist in reminding consumers of the health benefits and therefore act as stimuli for product purchase. From a study conducted by the National Heart Foundation (Blume, 2003) it was found that the most credible sources of information about healthy eating were the Heart Foundation (46% of respondents), dietician (38% of respondents) and doctor (33% of respondents); Food labels and food advertising were considered to be credible by fewer respondents (11% and 5% of respondents respectively). Sources of nutritional information regularly used are the NHF Tick (69%), ingredients list (56%), nutrient content claims (34%), food pyramid (34%) and glycaemic index (5%). However, it is the opinion of this author that advertising also has a place in reinforcing an already accepted health message.

Health Claims and Nutrient Content Claims

Since the use of health claims are not permitted in New Zealand under the FSANZ Food Regulations, nutritional content claims are the only permitted form for communicating the nutritional benefits of a product on the package and any related advertising. A study commissioned by ANZFA (Patterson *et al.*, 2001) showed nutrition claims do influence many people's decision to purchase. A study conducted by the National Heart Foundation showed that 34% of respondents regularly used nutrient claims in product purchase decisions (Blume, 2003). A study conducted by the USFDA has shown that the effectiveness of nutrient claims in communicating benefits is similar to health claims if the nutrient is well known and the benefits understood (Levy *et al.*, 1997). For example, consumers are highly aware of the role of calcium in bone strength and prevention of osteoporosis. Therefore, a nutrient content claim "high in calcium" implies to the consumer that the product is beneficial in preventing osteoporosis, without actually stating it. However, the study also indicated that there was no benefit in a claim (nutrient content claim or health claim) if the information was already well known. For example, a calcium claim on yoghurt had little effect, presumably because consumers already knew that yoghurt provided calcium (Levy *et al.*, 1997).

An UK/European study also found consumers expressed negative feelings towards unfamiliar nutrients, again emphasizing the need for well known nutrient components (Young, 1998). For nutrient content claims to be effective it is vital to choose nutrients whose benefits are well known and understood by New Zealand consumers.

Endorsements and Nutrition Symbols

From consumer research conducted by the National Heart Foundation in January and February 2002, the NHF Tick compared favourably as a source of Nutrition Information. From a computer aided telephone interview conducted on 401 New Zealanders, it was found that the NHF Tick is regularly used to make purchase decisions by 69% of respondents, with the highest NHF Tick usage by women 55-64 years. The National Heart Foundation was considered to be a credible source of information about healthy eating by approximately 46% of respondents, dieticians were the second most credible source (38%) and doctors third most important (33%) (Blume, 2003). However, a focus group study commissioned by ANZFA indicated scepticism towards the NHF Tick and nutrition symbols in general, with the argument that other products were often as good as or better than approved products (Patterson *et al.*, 2001). The Glycaemic Index (GI) was a less favourable nutrition symbol (probably due to a fairly limited awareness and use), 5% of respondents in the 2002 NHF survey regularly used GI to make purchase decisions (Blume, 2003).

5.1.6. Summary and Recommendations

Heart disease is a major health issue for New Zealanders and it is perceived by New Zealanders to be a serious health issue. People tend to underestimate their own personal risk of developing heart disease compared to the risk of the general population. However, people with a family history tend to have a higher perceived risk.

New Zealanders have a basic nutritional awareness of fat, saturated fats, salt, sugar, protein and fibre in relationship to the risk of heart disease. Despite this, there is still much confusion about the source and effect of certain nutrients. Furthermore, there are a number of nutrients associated with heart health for which no information on New Zealand consumer awareness is currently available. These nutrients include; soluble fibre, omega-3 fatty acids, plant sterols, soya protein, folate and antioxidants. Better understanding of consumer knowledge is necessary because any claims for the product will by necessity be nutrient content claims (not health claims).

Potential barriers to marketing a muesli bar with heart health benefits are resistance to fortified snack foods and the suggestion from available statistics that the age groups

most at risk/aware of heart disease are not large consumers of muesli bars. Therefore it is important to establish whether a muesli bar is perceived to be a suitable food product to deliver heart health benefits.

Purchase intent may be influenced by reminding consumers of the heart health benefits via (1) the use of health claims (if permitted) and familiar nutrient content claims (2) credible endorsements such as the NHF Tick and (3) educational and advertising material. Consumer research could identify which of these would be most persuasive for the product, or if a combination is most effective.

5.2 Focus Group Research

In the early planning stages of the project the intention was to use focus groups to obtain the initial consumer information and sort out questions that could be included in a subsequent consumer survey. However, it soon became apparent that the scope of the project was looking more like a PhD thesis than a masterate in the light of the amount of work that needed to be conducted on the extrusion part of the study. Consequently, a decision was made to minimise the amount of consumer work and use just a focus group to obtain any consumer information that was not available from any New Zealand studies, even though this information was available in overseas studies. The focus groups were necessary as there are always dangers in assuming New Zealand consumers behave and have similar beliefs and attitudes to overseas consumers. A decision was then made to only include people in the over 45 age bracket, and in particular those who had heart problems or were in danger of developing heart problems, as these people were more likely to be the target market for the proposed muesli bar.

5.2.1 Aims and Objectives

The objectives of the qualitative research were:

1. To determine the degree of concern for heart health of 30 Auckland consumers in the 45 + age bracket who either suffered from heart problems or lived with someone who suffered from a heart condition or did not suffer from a heart condition.

2. To determine the level of understanding of nutrition and various nutrients in relation to heart health of the above group.
3. To determine whether the described consumers perceived a muesli bar as a suitable product to provide heart health benefits.
4. To determine what heart health promoting nutrients were thought to be appropriate for use in a muesli bar.
5. To determine any potential barriers to market success.

5.2.2. Method

5.2.2.1. Data Collection

Focus group discussion was the consumer research method used to qualitatively assess consumer knowledge and opinions. A short survey (shown in **Appendix A-5**) was completed by the focus group participants prior to the commencement of focus group discussion to provide a quantitative indication of some of the main issues and for use as an assessment of any bias from dominant participants in focus group discussions. Ethics approval was obtained from the Massey University Human Ethics Committee (MUHEC) prior to conducting the research (Human Ethics Protocol 02/55), the approval letter can be found in **Appendix A-1**.

Four 2-hour focus group discussion sessions were conducted with 6-9 participants in each group. Focus group discussions were video taped with participants consent.

5.2.2.2. Participants and Recruitment

The primary target groups were defined as males 45-65years and females 55+ years that had either had heart problems or were concerned with heart health. This research was conducted on the primary target markets. Groups were recruited based on age, gender and heart condition. It was preferred (but not essential) that participants also ate muesli bars at least occasionally. Women were also included in some groups since in most cases they were the primary shopper. The target consumers for each focus group is summarised below in Table 5.1. In hindsight, it may have been more beneficial to include regular consumers of muesli bars that had a family history of heart disease in the study. However, as this group was not originally considered the primary target market they were excluded from this study. Time and resource constraints prevented further consumer study from being conducted within the scope of this project.

Table 5.1: Age and gender criteria for focus group participants recruited from the Rotary Club and Cardiac Clinic

	<i>Rotary Club</i>	<i>Cardiac Clinic</i>
1	8 males 45-65 years	
2	8 females 50-65 years	
3		4 Male 45-65years and partners
4		4 Male 45-65years and partners
5		8 females 50-65 years

Research participants were recruited through the Auckland Cardiac Rehabilitation Clinic and the Rotary Club of Auckland City West. Participants from the Auckland Cardiac Clinic were assumed to have had heart problems, whereas participants from the Rotary Club and partners in the cardiac group were assumed not to have heart problems, unless they voluntarily disclosed this information either in the survey or focus group discussion. Questions related to heart condition were considered to be too sensitive to use in the questionnaire.

Information letters (shown in **Appendix A-3**) and consent forms (shown in **Appendix A-4**) were distributed to potential participants through an organiser at the club/organisation. (Information letter to the organiser can be found in **Appendix A-2**). Interested participants posted the consent forms to the researcher to express interest and availability. Due to the difficulties encountered arranging a sufficient number of participants, the cardiac clinic mailed out information letters and consent forms to past members on behalf of the researcher.

Difficulties were encountered finding sufficient participants with heart problems in the 45-65 year age bracket, therefore participants up to the age of 70 years were included in the study. Females with heart problems were combined with the male + partners, as there was a poor response from this age group due to a limited number of women cardiac clinic members.

5.2.2.3. Focus Groups Sessions

The focus groups recruited from the Rotary Club of Auckland City West were held in the evening (6-8pm) in a meeting room at Unitech. The focus groups recruited through the Auckland Cardiac Rehabilitation Clinic were held at Nice and Natural Ltd in Glen Innes, also in the evening 6-8pm.

Participants were first requested to complete a brief survey (shown in **Appendix A-5**) that took approximately 10 minutes to complete to assess their awareness of heart health and nutrition; the survey was followed by a focus group discussion that lasted between 1½ and 1¾ hours.

Survey

In the survey some additional demographic information was sought including participants' health consciousness. Participants were asked whether they considered themselves to be health conscious and asked to give a reason for their answer. All participants that answered 'yes' to that question, (provided their comments reflected their answer) were classified as health conscious. This method of classification was considered to be valid since their answers were cross-checked with their comments. Examples of health conscious classification are shown in **Appendix B-1** (Tables B-1.1 and B-1.2).

Focus Group

The focus group discussion was structured with general questions and discussion to start, followed by specific questions. The researcher moderated the discussion to ensure all participants were given the chance to contribute their ideas.

The general discussion covered the following topics; heart disease concern, degree of influence on heart health, lifestyle and food choices to reduce risk, foods and nutrients that benefit heart health and common sources of nutritional information.

In the specific discussion, participants were asked their opinions about the following;

- Awareness and knowledge of the benefits of specific nutrients (their personal opinion and their opinion of the awareness of consumers in general) in relation to heart health
- The concept of a muesli bar to benefit heart health and properties that would be desired in such a product.

Participants were first asked about what properties/nutrients they would like to be included in a bar without prompts and then card prompts were introduced and the group was asked for a consensus on which nutrients should be included/excluded. A list of card prompts is shown in **Appendix A-7**.

Participants were probed for hesitations and asked their opinion on the appropriateness of each nutrient in a muesli bar.

- Promotion and benefit recognition
- Price and perceived value
- Purchase and consumption situation
- Potential target market
- Products that were marketed based on heart health benefits

Three products were discussed;

- Logicol/Flora Proactiv margarine spreads
- Benecol Cereal Bars
- Tip Top UP Omega-3 Bread

The concept, packaging, claims, nutrition information and overall perceptions were discussed for each product. Benecol Cereal Bars (marketed in the US and UK) and Tip Top UP Omega-3 Bread (recently launched on the New Zealand market) were presented to the group and discussed with the product in front of them, Flora proactiv./Logicol margarines were discussed without product reference.

The outline of questions and topics discussed can be found in **Appendix A-6**.

5.2.2.4. Analysis

Video recordings of the focus group were summarised and transcribed for each individual group by the researcher. For any direct quotes used, the demographic details of the participant (obtained from the survey) were recorded. All names were omitted from the analysis to protect the privacy of the participants.

The data collected from the surveys was grouped using Microsoft Excel Pivot tables. Statistical significance tests were not carried out on the data, as the sample size was too small to provide statistically significant differences. The responses given in the survey and during the focus group discussions were compared and any major discrepancies noted; major discrepancies may indicate bias from dominant participants or agreement within a group discussion situation. The comments from individual focus groups were compiled and an overall analysis was written.

5.2.3. Results and Discussion

Focus groups provide qualitative information only. The survey conducted on focus group participants must also be treated as indicative only due to the small non-randomly selected sample. A large scale survey would be needed to confirm the focus group results.

The results have been obtained from both the focus group discussions and survey completed by participants. All numerical results presented were obtained from the survey. All other results and discussion relate to the focus group discussion unless otherwise specified.

5.2.3.1. Participants

Focus Group 1

Focus group 1 consisted of nine male participants aged 45-65 years, six participants were health conscious and three not health conscious. One participant specified he had a heart condition in either the survey or focus group discussion

Focus Group 2

Focus group 2 was made up of seven females aged 45 – 65 years. All participants classified themselves as health conscious. One participant specified that she had high cholesterol in either the survey or focus group discussion.

Focus Group 3

Focus group 3 was made up of five males aged 45-70 years with a heart condition, and two female partners (assumed not to have a heart condition). All participants classified themselves as health conscious.

Focus Group 4

Focus Group 4 was made up of two males aged 45-70 years with a heart condition and their partners and two females aged 45-70 years with a heart condition. All participants classified themselves as health conscious.

Muesli bar Consumption Habits

It was determined from the survey that, overall, five participants ate muesli bars at least once per week, four participants fortnightly, 7 participants monthly, 4 participants occasionally and 8 participants never ate muesli bars. A breakdown of the muesli bar consumption habits in each group is shown in Table B-1.7, **Appendix B-1**. (The main reasons given for not eating muesli bars were that these participants considered muesli bars to be primarily for kids or they did not snack).

5.2.3.2. Heart Health Concern

Most of the individuals studied were of the opinion that the majority of people are concerned with heart disease and that the 45 – 65 year old age group were particularly aware. The survey conducted showed that 69% (20 out of 29) of the participants studied were concerned about heart disease or heart related conditions (cholesterol and/or blood pressure). A breakdown of participants' heart health concern is shown in Table B-2.1, **Appendix B-2**.

There were mixed opinions about whether young people (in the 20-30 age group) have concerns about the effect diet has on general and specifically on heart health; Rotary females felt that younger people are now much more aware of general health and well being, and also have cholesterol checks from a much younger age. However, others, particularly groups who had suffered heart problems think that people tend to ignore the problem until it involves either them personally or a family member. "My father had a bypass and it has made me more aware of it ...". [Female, 50-65years].

5.2.3.3. Heart Disease Prevention

Although awareness was high among participants, people in general were not actively trying to prevent heart disease. A number of participants expressed the view that many people do not concern themselves with heart health and despite the statistics presume that heart disease will not affect them. Most of the members of the cardiac groups had not tried to prevent heart disease prior to suffering heart problems, however they have since made major changes to their lifestyle including diet.

Despite this, in the survey the majority of focus group participants (25 out of 29) stated they did make food choices based on heart health - the four participants that didn't did not have a heart condition. A breakdown of whether participants made food choices

based on heart health according to their heart condition is shown in Table B-2.2, **Appendix B-2**. The heart health food choices participants made varied from avoiding products high in animal fats (butter, cream, fatty meats) and incorporating fruit, vegetables and cereals into the diet to taking omega-3 salmon oil pills, lecithin pills, coenzyme Q10 pills, and using Logicol "butter" spread. However, in this researcher's opinion, the general population may be less likely to make food choices based on heart health since the participants (cardiac participants who have dramatically changed dietary habits and people who are willing participants in a focus group on food and health) are likely to be more interested in health.

It was suggested by members of the Rotary groups that awareness is dependent on a number of factors including age group, race, socio-economic factors, family history, education and sports involvement.

All groups felt that heart disease was easily influenced by diet, and as a consequence it was just a matter of having the will to make the necessary lifestyle and dietary changes to minimise the risk.

Lifestyle Changes

It would appear that the focus group participants had made a number of lifestyle and dietary changes to lessen the risk of heart disease. These lifestyle changes included: regular exercise, quitting smoking, reducing alcohol consumption, reducing the quantity of food consumed for weight loss purposes, proper sleep and avoiding stress and making dietary modifications. The most common dietary changes made were: reducing/avoiding fat by consuming low fat milk and dairy products, lean red meat, chicken with skin removed and increasing fish consumption. Their cooking method had been changed from frying to grilling foods. The type of fats used was changed to monounsaturated fats such as olive oil. Salt was avoided by not using additional salt in cooking, and sugar intake reduced. Many avoided eggs, increased fruit and vegetable intake, and cereals such as Weetbix. Similar changes were noted in the National Nutrition Survey (Russell *et al.*, 1999).

In most cases the cardiac groups had made dramatic lifestyle changes after developing a heart condition. One group described the changes as "learning a discipline" to eat what

they were allowed. Since attending a cardiac recovery course (seven 2 hour sessions covering diet and other aspects of heart health) they now looked at things totally differently, and had read labels on food packages ever since.

These lifestyle and dietary changes made by the focus group participants show that some people who have suffered a heart attack or are at risk of developing heart disease are quite prepared to make drastic dietary and lifestyle changes to lessen the risk of having another attack or developing the disease so long as they get the correct nutritional and medical advice.

5.2.3.4. Awareness of Foods and Food Components

Fibre

The awareness of the heart benefit of 'dietary fibre' was very high in all groups. The survey showed that 72% (21 out of 29) of participants associated fibre with a heart health benefit. A breakdown is shown in Table B-3.1 (**Appendix B-3**). Moreover, from the focus group discussions it seemed that participants tended to associate fibre with general health benefits or the prevention of bowel cancer, rather than heart disease. Bowel cancer prevention is linked to the insoluble fraction rather than soluble fibre fraction. However, one participant in the cardiac group knew that fibre was beneficial for cholesterol reduction and therefore the heart.

No-one had heard of soluble and insoluble fibre and were therefore unaware of which foods are high in each component. In another NZ study conducted by Wiseman (1994), ninety three percent of respondents thought that more dietary fibre should be eaten, although no distinction was made between soluble and insoluble fibre. Wiseman (1994) found a strong consumer association between dietary fibre and heart health.

Most participants were looking for high fibre foods and believed that people have become more conscious of fibre over the last 10 years. Sources of fibre that participants were aware of included: brown bread, brown rice, breakfast cereals (wheat-bix, muesli, and porridge), certain vegetables, nuts, oat bran, wheat germ and linseed. The TipTop UP white bread did not appeal to most participants as the 45+ age group (the majority of the focus group panel) were generally wholegrain bread consumers, however they thought that it would be good for people that didn't like wholegrain bread. No sources

were considered better than others. The reasons given for eating high fibre products included; “for their general and intestinal health benefits, because they liked them and they give a sense of fullness”.

A ‘source of fibre’ claim for white bread made some consumers doubtful, knowing that fibre content in white bread was minimal.

These findings show that the participants studied relate to total fibre only and therefore this should be the primary emphasis of marketing. It also suggests that the heart health benefits of fibre are less well known than the other benefits associated with fibre, and the consumers may thus need to be educated about the benefits of fibre in relation to heart health. Consumers need to perceive the message about the food as ‘believable’ in terms of fibre; fibre was a nutrient that was considered desirable in a muesli bar (see Table 5.4 section 5.2.3.5). The positive image that fibre has in relation to general health and cancer prevention may or may not be advantageous, depending on whether a strictly heart health or a broader health image is desired.

Oats and Beta-Glucan

Although everyone had heard of oats and various oat products such as Jumbo Rolled oats or porridge, oat bran, and breads containing oat bran, only some participants had thought of them as being beneficial to heart health. People did not know which component in oats was responsible for the benefit and had never heard of beta-glucan the soluble fibre found in oats. The survey also showed that none of the participants associated beta-glucan with a heart health benefit (shown in Table B-3.2, **Appendix B-3**).

Oat fibre was not seen as being more beneficial than any other type of fibre. However, participants suggested that if consumers were informed of the benefits then it may influence their opinion. Based on the lack of awareness of beta-glucan, a more general fibre claim may be more relevant to New Zealand consumers and have greater impact than a statement that the product contains oat beta-glucan unless consumer education was undertaken.

Psyllium

Virtually no-one had heard of the soluble fibre psyllium which is derived from Psyllium husks. The survey showed that only one participant associated psyllium with a heart health benefit (Table B-3.3, **Appendix B-3**). There was some initial response, however it was found that they were confusing this product with the mineral, selenium. It was clear that people would not be drawn to a product that “contains psyllium”, unless there was considerable consumer education.

Fat

All groups were aware of both the total fat levels and type of fat in a food provided the information was supplied on the product’s packaging. The discussion about dietary changes to reduce the risk of heart disease focused on both reducing total fat intake and changing to healthier fats and oils. However, the discussion specific to fat identified that people are predominantly looking at the total amount of fat in products. The cardiac groups were thinking in terms of allowable limits with <5g per serve being good and <10g OK.

In the survey, almost everyone (28 out of 29 participants) associated low fat with heart health (Table B-3.4, **Appendix B-3**), whereas fewer (20 out of 29 participants) associated low saturated fat with heart health (Table B-3.5, **Appendix B-3**), presumably because this implied to some that total fat may be high.

Although everyone was aware of saturated, monounsaturated and polyunsaturated fats and knew that saturated fats were ‘bad’ fats and mono- and polyunsaturated fats were ‘good’ fats, fewer people used this information to compare or decide on product purchase. The total fat content was more commonly used in the purchasing decision process. Despite this, people consumed certain foods such as olive oil, avocado and fish for their heart health benefits presumably due to the level of unsaturation of the fats in these foods, or possibly due to a general belief in them being ‘healthy’.

This attitude towards fat implies that addition of monounsaturated or polyunsaturated fats to a heart health cereal bar, although beneficial, may be perceived negatively by the consumer when looking at the total amount of fat on the nutrition information panel. Similarly, replacing existing saturated fat with these healthier fats may not influence

them much either. A claim for low fat was more influential than a low saturated fat claim as participants did not assume that total fat was also low. This is an important consideration in the development of the product.

Omega-3

In most of the focus groups fish (due to omega-3) was mentioned in general discussion (prior to being asked about awareness specifically) as a food that was consumed for the heart health benefits that it provides. “I would buy tuna to have at lunch time because it is better for your heart than meat, and there is a great variety of tuna” [Female, 50-65 years, health conscious]. Most were aware that it was the omega-3 content in fish that was beneficial. “I eat a lot of salmon because it has a high omega-3 content” [Female, 50-65 years, health conscious].

From the focus group discussion it appeared that there was a high awareness of omega-3 in all groups studied, yet it was suggested that not everyone would be aware of it. The survey indicated that all participants with a heart condition associated omega-3 with a heart health benefit, compared to only 3 out of 14 of the participants who did not have a heart condition. A numerical breakdown of the responses is shown in Table B-3.6, **Appendix B-3**.

Most people associated omega-3 with fish or fish oil, and cod liver oil, tuna and salmon were considered to be excellent sources of these fatty acids. Many (11 of the 18) participants that recognised the heart benefit of omega-3 also consumed fish. Refer to Table B-3.7, **Appendix B-3** for details. This indicates a positive association between awareness and behaviour. Some of the participants had also seen a margarine spread that contained omega-3. Research conducted by Leatherhead in the UK in 1995 also indicated that consumers thought that an omega-3 spread was good for heart health, with the same benefits as cod liver oil (Young, 1998). A few participants had heard of omega-3 eggs, but were sceptical about how this was achieved and how active it would be. It was felt that it was probably better to get the benefit from eating fish. Most who were aware of the heart health benefits of omega-3 mentioned recent press coverage in the health section of the Herald. There was very little awareness of plant sources of omega-3 such as flaxseed. Some participants took omega-3 capsules for their health benefits. Although consumers associated omega-3 with heart health benefits, there was

confusion about the exact benefit, i.e., some assumed a cholesterol lowering benefit. From the evaluation of Tip Tops omega-3 fortified bread it was evident that participants were not aware of the different forms of omega-3, let alone being able to relate particular forms to superior benefits.

Some concern was expressed that there may be a fishy taste associated with products containing omega-3. A similar concern was expressed by UK consumers (Young, 1998).

Plant Sterols

In the survey, very few participants associated plant sterols with a heart health benefit; those that did had a heart condition (3 participants) or their partner had a heart condition (2 participants). Refer to Table B-3.8, **Appendix B-3** for details.

From the focus group discussion, some participants in the Rotary groups and most in the cardiac groups had heard of plant sterols. All awareness was in relation to the cholesterol lowering spreads, as these are the only products containing plant sterols currently permitted on the New Zealand market (although participants were not told that plant sterols were currently only allowed in margarine spreads). Some participants were unaware of plant sterols when discussed out of context of cholesterol lowering spreads. For example, some people had not heard of plant sterols but were aware of the spreads containing them, i.e., Flora Proactiv (Unilever) or Logicol (Meadowlea). There were 2-3 participants in each group that had either tried one of the above spreads or consumed it regularly. Participants' knowledge about plant sterols, including those that consumed the product on a regular basis was very superficial; most people did not know what plant sterols were but knew only that they were meant to lower cholesterol and were therefore beneficial for heart health.

Soy

Most people had heard of soy and related it to soy products such as soy milk, tofu and soy sauce. However, soy was not always viewed positively, with issues about genetic modification noted in every group. Non-soy consumers were often put off by the unusual taste characteristics, whilst soy consumers found this quite acceptable. One participant reported consuming soy for the benefits it provides during menopause,

others have heard that soy causes hormonal imbalances in young people. Most focus group participants did not associate soy with heart health benefits, although the small consumer survey showed that approximately 20% of participants (mostly those with heart problems) thought that soy provided a heart benefit. Refer to Table B-3.9, **Appendix B-3** for details. Participants perceived soy to be consumed mostly by vegetarians and people with dairy allergies. In contrast, US consumers commonly associate soy with heart benefits. This higher awareness is probably due to the long term educational campaign by the US Soy Council and the FDA health claim that can be made about soy in relation to heart health.

Folate

Awareness of folate was fairly low and was not associated with a heart health benefit. The survey indicated that only 38% (11 out of 29) of participants associated B vitamins with a heart benefit. Refer to Table B-3.10, **Appendix B-3** for details.

Antioxidants

The survey showed that 41% (12 out of 29) of participants thought that antioxidants provide a heart health benefit. Refer to Table B-3.11, **Appendix B-3** for details. It was mostly the participants with a heart condition or their partners that made this association.

Most participants associated antioxidants with vitamins, however some were unsure of what antioxidants were. It seemed that participants were not specifically looking for vitamins in food products. In comparing two products, some would pick the one with added vitamins, however other factors also came into it.

Sodium

Members of all groups were aware that low sodium was beneficial in the prevention of heart disease as salt "hardens the arteries". The survey showed that 75% of participants associated low sodium with a heart health benefit. Refer to Table B-3.12, **Appendix B-3** for details. Most people were aware that processed foods and takeaway foods are very high in salt. Those that have problems related to thrombosis were particularly aware, with one participant commenting on the high salt content in the Tip Top Omega-3 bread that had been discussed, as well as most other breads. Several participants in the female

Rotary group recalled ‘low sodium’ claims on some of the Watties products, however there was some scepticism about how low this level was. Many participants read and compared labels for salt contents or ‘low salt’ claims, and made choices based on this provided taste was not compromised. There appeared to be greater concern and attention paid to certain products known to have high salt contents (e.g. Pasta sauces). However, knowledge about how much salt they should have may be lacking (with the exception of participants with a thrombosis related concern) as they did not quote a maximum sodium level, but were sceptical about low salt claims. However, all groups commented that humans needed some salt to maintain electrolyte balance and prevent cramping.

Summary of the Awareness of Foods and Food Components

Table 5.2: Summary of the awareness of foods and food components that provide heart health benefits

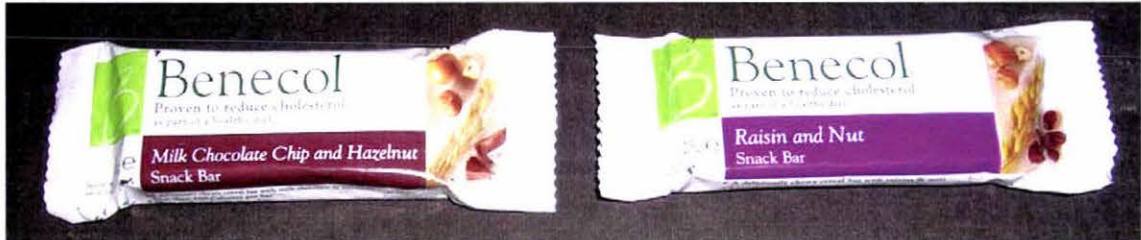
<i>Nutrient</i>	<i>Awareness</i>	<i>Understanding of Heart Benefit</i>
Fibre	High	Low
Soluble Fibre	None	None
Beta-Glucan	None	None
Psyllium	Low	Low
Fat	High	High
Monounsaturated	High	Moderate
Polyunsaturated (omega-3)	High	Moderate
Plant Sterols	Moderate	Low-Moderate
Soy	Moderate	Low
Folate	Low	Low
Antioxidants	High	Low

5.2.3.5. Market Considerations

Important issues for the marketing of a ‘heart healthy’ muesli bar were identified through the discussion of a proposed heart health bar and the discussion of other functional food products on the market. The products used for this discussion were Flora proactiv./Logicol margarine, Benecol snack bars and Tip Top UP omega-3 bread. It is assumed that issues raised about these products would be applicable to other functional food products as well, and thus the discussions provide an insight into how products should be marketed.

Product - Proposed Heart Healthy Muesli Bar

Figure 5.1: Product Concept - Benecol Snack Bar



Product Description: 25g snack bars that contain plant sterols, presented in two flavours: Milk chocolate chip and hazelnut and Raisin and nut

Claims/statements on pack:

Front panel: “Proven to reduce cholesterol as part of a healthy diet”

Side Panel: “Benecol is a range of delicious foods containing an exclusive ingredient, plant stanol ester, that is proven to reduce LDL (bad) cholesterol by as much as 14%. To continue the cholesterol lowering effects of Benecol foods, you must eat 2-3 servings of Benecol foods every day as part of your healthy diet.”

In each focus group, the concept of a heart healthy muesli bar was discussed. Participants were asked their opinion of the product concept and desired properties in such a product.

Concept

The concept of a heart health bar was viewed fairly positively by most participants. People who had suffered heart problems were particularly welcoming of the idea of a healthy snack that would fit into their heart healthy diet. However, if the product were to be accepted as a credible heart health bar then the health benefits must be proven; in participants’ minds benefits were accepted to be “proven” if the product was approved by the National Heart Foundation. Consumers perceived the NHF tick as an impartial endorsement of the product’s efficacy, despite some scepticism. The product must also taste good and be reasonably priced. “Although we want things that are good for us, price comes into it as well” [Female, 45-65 years].

A number of potential barriers to market success were identified. There were mixed opinions about the intrinsic healthiness of muesli bars, whilst some viewed these

products as healthy (due to cereals, fruits and grains), many were concerned about the high sugar content common in such products. Similarly, focus groups conducted in the US (Schmidt *et al.*, 1998) found that consumers had mixed views on fortified snack foods. Those in favour saw a health benefit as a great bonus for a product that they were likely to eat regardless. Yet others expressed concerns about the fat content of such foods. A couple of participants in the Rotary male group felt it was more important to change overall eating habits than to add extra nutrients (fibre, vitamins and minerals etc) to specific foods. This is the opinion of many dieticians and physicians. Some physicians in a US Study (Schmidt *et al.*, 1998) felt that recommending such products is against the ultimate goal of changing peoples' approach to eating. Despite a willingness to consider functional foods, health professionals would still prefer to see people eating traditional foods as part of a balanced diet. "...There's more than just lycopene in tomatoes". (Schmidt *et al.*, 1998). Nutritionists at the National Heart Foundation held a similar view (Roberts, Personal communication, 2002).

It was concerning from a market perspective that one of the male Rotary groups did not snack at all. However, the participants in the other three groups did snack, and informal discussions with the target age group also suggested that snacking is the norm. Although concern was expressed about healthiness, it was evident that convenience is often an overriding factor. However those who had suffered heart problems were more aware of what they were "allowed" and only departed from their diet for occasional treats. However, overall there tended to be greater interest in the healthiness of breakfast than snacks. People that did not tend to snack frequently suggested producing a heart healthy breakfast cereal as an alternative or possibly a breakfast bar for convenience. However, as a breakfast bar the serving size would need to be increased considerably "I would need to eat 2-3 bars".

Another concern is that shopping and eating patterns seem to be habitual, and new product adoption amongst this age group was relatively slow. Whilst some participants purchased/consumed muesli bars regularly (55% consumed muesli bars at least once per month), others only purchased/ate them as a convenience food on holiday or when playing sport. There could be some difficulty in persuading older consumers to purchase bars that they commonly stereotyped as a kids' lunchbox product. However, an obvious positioning as a heart health bar may assist in product adoption.

Desired Properties and Nutrients

Groups were asked what they would look for in a heart healthy bar. Prompt cards for nutrients and common nutrient content claims were presented. Actual levels of nutrients were not included. A list of the prompt cards used may be found in **Appendix A-7**. Claims of ‘Low Cholesterol’, ‘Low Sugar’ and ‘Low Salt’ were not included as prompts, but were spontaneously mentioned as desirable by one group.

The claims (and properties) desired for a heart health bar are outlined in Table 5.3, and the nutrients desired are outlined in Table 5.4.

‘X’ denotes that the property or nutrient was desired by group consensus.

- - indicates a strong negative feeling towards the nutrient/property was expressed by members of the group

A blank space indicates neither a positive nor negative reaction

Table 5.3: Claims/Properties desired in a Heart Health Cereal Bar

<i>Property</i>	<i>Rotary M</i>	<i>Rotary F</i>	<i>Cardiac 1</i>	<i>Cardiac 2</i>
Heart Tick	X	X	X	X
Low Fat	X	X	X	
Low Saturated Fat	X	X		X
Low Cholesterol*			X*	
Low Sugar*			X*	
Low Salt*			X*	

* These properties were not included as prompts but were mentioned as being important by one cardiac group.

Table 5.4: Nutrients Desired in a Heart Health Cereal Bar

<i>Ingredient</i>	<i>Rotary M</i>	<i>Rotary F</i>	<i>Cardiac 1</i>	<i>Cardiac 2</i>
Omega-3	X	X	X	X
Plant Sterols	- -	- -	- -	-
High Fibre			X	X
Oat fibre/B-glucan		X		
Psyllium				X
Soy Protein		*initially	- -	X
Vitamin E	X			X
Folate	X			
Thiamin (vitamin B1)		X		
Zinc	X	X		
Iron	X			X
Riboflavin	X			
Calcium		*initially		X

Table 5.3 on the previous page shows all groups desired to see the Heart Foundation Tick on products (consensus all groups). This was expressed as being the single most important factor. Low fat and/or low saturated fat was an important consideration also. However, there was some confusion about which was the more beneficial. Low cholesterol, low sugar and low salt were also expressed as being particularly important by one group, since these properties were not included as prompt cards in the same way as the other properties, the importance of this was likely to be underestimated.

Table 5.4 (previous page) shows that the inclusion of omega-3 was desired by all groups, including those that stressed the importance of a low fat product. Plant sterols were avoided by all groups due to their unfamiliarity. Note, it was previously indicated that most participants had in fact heard of plant sterols, however few participants understood their benefits or what plant sterols were. The cardiac groups wanted the products to be high in fibre, the Rotary female group specified the inclusion of oat fibre (probably due to the education of the benefits of soluble fibre from oats that had been provided in the earlier part of the discussion) and one of the cardiac groups specified psyllium. There were mixed feelings on soy protein, one of the cardiac groups recommended its inclusion, whilst the consensus of another group had strong reservations about soy. The Rotary womens group included it initially because they liked the idea of a protein source but then decided against its inclusion because of GM issues and finally stated a preference for receiving the protein from nuts. Two groups desired the inclusion of vitamin E, and one group desired folate, another thiamin.

The inclusion of zinc, iron and calcium by some groups was unusual as these nutrients do not provide any substantiated heart health benefits. The groups included these nutrients for their general health benefits as they were seen as lacking in the diet.

The desire for familiar ingredients was consistent with the comments given in the evaluation of other functional food products. The importance of nutrient familiarity was expressed in the evaluation of Benecol cereal bars. Some of ingredients, such as plant sterols were poorly understood. "Plant sterols - sounds like steroids, manufactured – don't know if I need too much of this stuff". Some participants stated that "if you don't understand the ingredient, then you think the company has made up the name, especially since GE is floating around in everybody's minds".

Product Benefit

The size of the benefit was considered important, for example, how much the product lowered cholesterol. In the evaluation of Benecol bars when members of one of the cardiac groups read the packaging and saw that it lowered LDL cholesterol by up to 14% they thought they may try the product. Yet, in the discussion of the cholesterol lowering margarines (Flora proactiv. and Logicol) participants were sceptical about the amount the product would lower cholesterol. Bearing in mind that the people need to read the label to realise this information, it is important that the product has other characteristics to draw attention to it.

Participants were aware of an ‘actual benefit’ vs a token amount of an active ingredient added for marketing purposes. In the evaluation of Tip Top UP omega-3 bread, some of the participants were sceptical about the amount of omega-3 in the product and saw it as more of a sales pitch than of potential benefit. “Surely so little omega-3 in there, it wouldn’t do you any good”. In a survey in the UK, consumers were also concerned about the amount of omega-3 you would get (Young, 1998).

Serving Size and Dosage

When considering the purchase of the product the serving size of the product that one would need to consume to obtain a significant portion of the recommended daily intake, and therefore benefit, was considered.

The quantity of Logicol and Flora proactiv. recommended in order to obtain a cholesterol lowering benefit (25g per day) was known by those that had tried the product and thought to be much too high, compared with their actual usage rate of margarine and the Heart Foundation recommendation (5g margarine per day).

The level of omega-3 in Tip Top UP bread was perceived to be low “Surely with so little omega-3 in there it wouldn’t do you any good”. Two servings (4 slices) of bread provide 25% of the adequate intake of omega-3 DHA recommended by the International Society for the Study of Fatty Acids and Lipids.

Therefore, it is important to ensure that a realistic serving of the product makes a significant contribution to daily requirements of the active ingredient.

Other Product Characteristics

Other factors that would come into the decision to buy the product included: product taste, size, and performance in product usage situation; for example, participants wondered how Tip Top Up bread would toast, and whether the Benecol bar, a snack product, would provide enough energy to sustain them until lunchtime.

Packaging

Pack Format

A heart healthy muesli bar should be purchaseable in both multi-pack format and as single bars. One group (Rotary males) suggested that the number of bars per pack should be reduced (4 or 5 vs 6 std bars) or the bar size should be reduced to ensure the product did not exceed their price bar. However, women shoppers were quite aware of the variation in the number of bars per package and the variation in the size of the bars. They would prefer to see an honest sized pack, with the same size of bars as existing packs, rather than having a half empty box. Bold and attractive packaging with graphics that are perceived by consumers to be suitable for food is important. Many participants disliked the packaging design and colour scheme used for the omega-3 fortified Tip Top Up bread, some likened it to the packaging used for laundry powder.

Brand

One group (Rotary male) thought it would need to have an obvious name such as “Heart Bar” to distinguish it from others, however all other groups did not see a need for this. In fact, the branding and packaging of the Benecol Bar meant that it was perceived to be a medical product rather than a food. “It looks like a cold remedy”, “I would eat it if I was sick”. This perception is undesirable, as people prefer positive health motivation (Heasman and Mellentin, 2002). Refer to chapter 2, section 2.7.2.1.

Claims and Endorsements

Nutrient Content Claims

One group (Rotary Female) would like the front panel of the packaging to be labelled with the amount of sugar, and nutrient content claim statements such as “contains omega-3”.

There was some scepticism about the substantiation of claims throughout all discussions showing a general lack of trust in food manufacturers. For example, participants questioned how much Flora proactiv. (margarine containing plant sterols) lowered cholesterol.

NHF Tick

It was strongly advised that the product has the NHF Tick on the front of the pack. The NHF Tick had very high awareness and support in all groups. In the survey, 90% of participants (26 out of 29) thought that the NHF Tick indicated a product was good for heart health. In all four focus groups, the topic came up in general discussion several times without the moderator asking their opinions about it - an indication of its importance. Consumers liked the idea that the products with the Tick had been evaluated by the Heart Foundation, an impartial and credible organisation. The Tick is an easily identifiable symbol that people can use to assess a product. It is used as a sole criterion of the product without concerning themselves with details “it says whether it is something you can have” [Male, cardiac] or as an indication that they should read the label further. Bold, large symbols and lettering can be of importance with the target age group, “it can be a struggle to read the tiny print” [Female, health conscious], particularly if shoppers forget their glasses” (Patterson *et al.*, 2001).

The presence or absence of the Tick was noted when the participants evaluated products. One group (Rotary male) identified the lack of the Heart Tick as a downfall of the Benecol Bar, a product containing plant stanol esters and marketed as a heart health product. The presence of the Heart Tick on Tip Top UP bread, containing omega-3 fatty acids, was considered to mean more than all other information written on the pack by members of one of the cardiac groups.

Most participants were aware that it costs money to have products endorsed by the Heart Foundation, and therefore some products that didn't have the tick were equally good or better than those with the Tick. Regardless, they still felt that the tick is a good indicator of the healthiness of a food product. A study commissioned by FSANZ found some sceptical views toward the NHF tick and nutrition symbols (Patterson *et al.*, 2001), possibly due to a recent current affairs program that had revealed costs associated with the tick approval (Patterson *et al.*, 2001). Some participants alluded to

products carrying the NHF Tick being more expensive than their counterparts without the Tick, and mentioned that they resented having to pay more for products with the NHF Tick.

Nutrition Information Panel

The nutrient information panel is an important source of information for people checking fat content and other nutrient contents of food products. However, the nutrition information panel can be daunting if it contains information about unknown nutrient components. The nutrition information panel on the Tip Top UP Bread was a source of great confusion. Participants were overwhelmed with the various forms of omega-3 listed on the nutritional panel. “ALA, EPA...it’s goobledy gook”.

Promotion

Positioning and Target Market

It was suggested that health conscious people and sports people would be interested in a heart healthy bar, however if the product tasted good and was affordable the appeal would be more widespread.

Product Information

Source of Information

The main source of nutritional information for the cardiac groups was from a cardiac recovery course that they had attended. Other groups learnt about nutrition from the radio and reading articles. Sources of articles included the Herald, Consumer Magazine, popular diet books (such as The Liver Cleansing Diet), Millenium Healthy Eating Guide and pharmacy brochures. No-one specified their GP or a nutritionist as a major source of nutritional information.

Amount of Information

Functional Foods products tend to be accompanied by information about the nutritional and health benefits of products (e.g. Flora Proactiv.), however it was evident that the participants were faced with information overload and found a lot of the information unnecessary. For example, one of the participants [cardiac, male, 45-65 years] commented that Flora Proactiv margarine came with a booklet, and although he had bought the product quite often, he had always thrown the booklet away. Participants

were more interested in whether it is nutritionally acceptable (fits into a heart healthy diet), via an endorsement such as the Heart Foundation Tick, rather than the science of what is in it. They like to read the nutritional panel, but anything past that becomes too time consuming. Detailed information should be presented to health professional only and simplified health messages presented to the consumer. Short, concise, easily understood educational statements about the health benefits of the product are required and/or the use of the NHF Tick.

Price

Most consumers who had not experienced heart problems would expect a multi-pack of 'Heart Bars' to be comparably priced to standard muesli bar products, whilst others, particularly those who have experienced heart problems, were prepared to pay slightly more, approx 20% more, or up to a maximum of \$5 - \$5.50 per 6 bar multi-pack in some cases. The consensus on pricing in the female Rotary group was that people would be prepared to pay \$4.20 (20% more than the average price of approx. \$3.50 per multi-pack), or possibly \$4.50 maximum for a 6 bar multi-pack. However, if the product tasted really good, or if the bar size was larger than standard bars then they would be prepared to pay more. One participant would be prepared to pay \$5.25, but most saw \$5.00 as a barrier. It was evident that some people only purchased bars individually and there was a wide range between prices paid from \$1 per bar to \$2.50 per bar.

The reason for purchase also had an impact on the price participants were prepared to pay for the product. Those with cholesterol problems would buy such a product based on its cholesterol lowering health benefits. In this case, price is not always an issue. Several participants purchased Logicol for example which is much more expensive than ordinary margarine. They were prepared to pay more for a more effective product. "However, if you are buying for your family it becomes more of an issue".

From a nutritional policy point of view, products that may offer potential health benefits should be priced to be accessible to a majority of consumers (Sadler and Saltmarsh, 1998). A price premium of 20 percent is at the lower end of the scale for acceptable pricing of Functional Foods products according to Functional Foods market literature. (LFRA, 2001). Higher pricing is a common cause of product failure, although, some niche products command up to five times the price of standard products.

Many participants had been put off by the cost of products such as Logicol and Flora Proactiv margarine. Therefore, products must be reasonably priced. A small percentage of consumers, namely those with a heart problem, may be willing to pay a greater premium.

5.2.4. Discussion/comparisons

5.2.4.1. New Zealand/Australia

The results found from these focus groups are generally in agreement with the limited amount of New Zealand and Australian data that was available. Therefore, this information provides a relatively reliable indication for the preliminary design of the product and marketing plan for a heart healthy muesli bar.

Heart Health Concern

The focus groups indicated that people were concerned about heart health as a major health issue. However, participants also expressed the view that people don't think it will happen to them. This statement is in agreement with research conducted by Wiseman (1995) who found that 98% of respondents in a mail-out survey thought that heart disease is a serious problem for New Zealanders, with fewer (54%) participants believing that heart disease may affect them personally in the future. UK and European consumers also felt they had a relatively high degree of influence in the prevention of heart disease and a number of heart disease risk factors (high blood pressure, high cholesterol and obesity) compared to other conditions (Young, 1998).

Dietary Changes

The dietary changes made by focus group participants that had been diagnosed with a heart problem are similar to those noted by Wiseman (1994) in a study on "the beliefs about food components, foods, fat and heart disease in New Zealand" and the National Nutrition Survey (Russell *et al.*, 1999).

Nutrient awareness

In most instances, Wiseman (1994) reported similar results to those found in the focus groups in terms of the awareness of nutrients and their relationship to coronary heart disease. The only discrepancy is that 60% of the respondents in Wiseman's study made an association between protein consumption and reduced risk of coronary heart disease.

This belief was not held by the focus group participants in this study. Wiseman's (1994) study did not investigate consumer awareness of soluble fibre (as distinct from total dietary fibre), omega-3 fatty acids, plant sterols, soya protein, folate and antioxidants. There is no published information on New Zealand consumers' awareness of these nutrients in relation to heart health.

A study conducted by FSANZ suggested that consumers often have knowledge specific to health problems that affect themselves or a family member (Patterson *et al.*, 2001). The focus groups didn't provide evidence of marked differences in knowledge between those that suffered from heart problems and those that hadn't, however it did show that participants who had suffered from heart problems had made major lifestyle and dietary changes.

Promotion/labelling/effect of claims

Focus group participants used nutrient content claims (such as "low fat" and "high fibre") when making purchase decisions, at least to identify a product and read the nutritional information. These findings are in agreement with a study conducted on behalf of ANZFA (Patterson *et al.*, 2001) that showed nutrition claims do influence many peoples decision to purchase.

Participants in this focus group study also considered an endorsement by the Heart Foundation to be vital. Findings were in agreement with consumer research conducted by the Heart Foundation, it was reported that 94% of consumers viewed the Tick positively (Blume, 2003). However, a study commissioned by ANZFA found some sceptical views toward the NHF tick and nutrition symbols (Patterson *et al.*, 2001).

5.2.4.2. US

The US has been identified as the market with the greatest potential for a heart health snack product, and therefore would be the chosen market for export. Thus, it is important to highlight major differences that exist between New Zealand and US consumers that may impact on the bar composition or product promotion.

New Zealand consumers have negative opinions about soy, however, the situation in the US is very different. The awareness of soy protein in the US is much greater than in

New Zealand, probably due to the promotional efforts of the Soy Council and more recently the FDA approval of a heart health claim in relation to soy. The use of soy is widespread in the US and well accepted. Therefore, the inclusion of soy protein would be more suitable in a product exported to the US than it would be for the local market.

The ability to make heart health claims in the United States means that it may be easier to convey messages about health benefits, and it is assumed that the consumer awareness of nutrients/food components for which claims can be made will increase over time. Therefore, inclusion of nutrients for which health claims can be made may be more favourable than promotion of the same nutrients in New Zealand where health claims are not permitted. However, since health claim are not the only important factor, it is recommended that US consumer preferences are investigated further before developing a product for the US market.

5.2.5. Conclusions and Recommendations

Degree of Concern for heart health

The focus group results suggest that most of the participants in the 45-65 age group were concerned about heart disease and related conditions (particularly cholesterol and high blood pressure). Hence, it would seem that food products that provide heart health benefits could be of relevance to New Zealand consumers, so long as a larger study carried out throughout the country confirmed the above findings.

Despite an apparent high level of concern, this study suggests that, many of the participants still do not take preventative measures until they or a family member has suffered from heart problems. Many participants in this study who had a strong interest in health also made lifestyle and dietary choices to reduce the risk of coronary heart disease. Therefore, food products, including a heart health snack bar, are most likely to be adopted by people such as the participants of this focus group study who are very health conscious or people who have had a heart attack or have a family member who suffers from heart problems. It is at these groups of consumers that the marketing efforts should be directed.

Understanding of nutrients in relation to heart health

Consumers are more likely to purchase the product if they recognise it provides a heart health benefit. Consumers recognize a heart benefit by the presence of endorsements, and nutrient content statements, provided they are aware of the benefit provided by the nutrient. Consumers were more aware of some nutrients in relation to heart disease than others.

Fat

- There was a high awareness of the detrimental effects of a high fat diet in relation to coronary heart disease and good awareness of the different types of fat.
- There was a strong awareness of the heart health benefits of omega-3 from marine sources, but plant sources (such as flaxseed) were poorly recognised.
- Food choices were still dominated by the total fat content.

Consequently, under current consumer perceptions, the proposed muesli bar would need to be formulated such that the total fat level remained relatively low and the amount of saturated fat in the bar was minimized and replaced with mono- and polyunsaturated fats, particularly the omega 3 oils.

Plant Sterols

There was some awareness of plant sterols, mostly in association with the margarine brands that contain plant sterols (Flora Proactiv and Logicol). However, the focus groups suggested that these plant sterols should not be included in the bar because some participants thought that they were unnatural i.e., “manufactured”.

Fibre

- Awareness of dietary fibre was high
- Awareness of soluble fibre was non-existent
- Benefits of fibre were not always linked to heart health.
- The source of dietary fibre was considered unimportant, however, awareness of oats as a source of fibre was much greater than that of psyllium.

Hence consumer education about the heart health benefit of fibre is required. The use of oat would be better recognized than psyllium.

Low Salt

Low salt was associated with a heart health benefit.

Soy

Although most people had heard of soy, it was not viewed positively and not known to benefit heart health.

Antioxidants

There was low awareness of any heart benefit of antioxidants

Perception of a muesli bar as a product to provide heart health benefits

In this study the response to the concept of a muesli bar that provided heart health benefits was positive, particularly from those that suffered from heart problems. Some participants who did not currently purchase muesli bars indicated that they may do so. From this, the indication is that it may be worthwhile marketing such a product and in doing so may grow the snack bar market.

Heart healthy ingredients considered appropriate for use in a muesli bar

The properties that the participants desired most in a heart healthy bar are; a product that is low in fat (and/or saturated fat), contains omega-3, is high in fibre and has the endorsement of the Heart Foundation (NHF Tick). These are nutrients that consumers are familiar with and perceived to provide a heart health benefit. There were mixed views on the inclusion of soy protein and strong negative feelings were expressed about the inclusion of plant sterols. There was some desire expressed for the inclusion of vitamin E (an antioxidant) and several vitamins and minerals that people felt were generally lacking in the diet. The amount of these nutrients must make a significant contribution of the recommended daily requirements for the amount required to provide a benefit.

Potential barriers to market success

- Poor taste
- Lack of trusted endorsements
- Packaging and branding that portrays a product as a medical product rather than a food product.

- Very high price premiums – a 20% premium (retail price of \$4.20 per multipack was generally considered reasonable by participants), \$5.00 per multi-pack was considered to be the maximum price that any participants would pay.

General Recommendations

Products must also taste good, be reasonably priced and provide sustained energy. Development of a heart health bar should endeavour to meet the Heart Foundation requirements and contribute a significant level of fibre. Omega-3 polyunsaturated fats should be added only if a low fat claim can still be made. Whilst ingredients that provide good taste should be used, a balance between taste, price and nutritional benefit is required.

The product should be packaged in bright packaging with clear branding and statements; including the NHF Tick and possibly major nutrient content claims. It is important that the branding and packaging portray the product as a food rather than as a medical product ie. The functional food product should be available in multi-packs (sold in supermarkets) and in displays of individual bars (sold at the supermarket check-out and convenience locations). Consumers would be prepared to pay a slight premium (approximately 20%) to receive health benefits, a maximum price of between \$4.20 and \$5.00 per multi-pack containing 6 standard sized bars was suggested. Pricing was dependent on purchase motivation, with those suffering from heart problems or concerned with heart health likely to pay more.

The inclusion of soluble fibre and to a lesser extent omega-3, would require some consumer education of the heart health benefits. If soy, plant sterols or antioxidants were to be included, these would also require considerable consumer education. Educational material on the heart health benefits should be kept very simple. Concise, easily understandable statements, and the NHF Tick are recommended. Detailed information, such as pamphlets is deemed to be unnecessary to the majority of consumers. People that had suffered from heart problems had learnt about heart healthy foods from a cardiac nutritional course that cardiac patients attend. It is recommended that a heart health bar be presented at such courses or at cardiac rehabilitation clinics.

6. SCREENING

The following heart health benefit nutrients were screened against set criteria to determine which would be the most appropriate to be incorporated in an extruded ingredient;

- Omega -3 fatty acids
- Monounsaturated fatty acids
- Soluble dietary fibre
- Plant Sterols
- Soy protein
- Folate
- Vitamin E

6.1 Screening Method

Selection and Weighting of Screening Criteria

The number of nutrients was small as the investigation had been limited to nutrients that provide a heart benefit (i.e. informally pre-screened against the criteria ‘heart benefit’). Nutrients identified in the nutrition review as providing a heart health benefit were screened. Nutrients that were excluded by the focus groups were included in the screening because Nice and Natural intend to export a heart healthy bar to the US at some stage. Probability screening was used to determine which would be the most appropriate ingredient(s) to be incorporated in an extruded ingredient. Each nutrient was scored against five screening factors set by the management team at Nice and Natural Ltd. Each factor was given a percentage weighting as an indicator of its relative importance in the screening scheme. The screening factors and relative weightings are outlined in Table 6.1 below. For details on the development of the screening factors and weightings, refer to **Appendix C1**.

Table 6.1: Product Screening Criteria

<i>Screening Criteria</i>	<i>Weighting (Score out of 100)</i>
Health Benefit	45
Positive Consumer Awareness of Health Benefit and Acceptability in a Muesli Bar	25
Processing and Stability	10
Regulations	10
Cost	5

Definition of Screening Criteria

The screening criteria were defined and definitions were included in the instructions on the screening sheets to minimise interpretation errors. The criteria were defined as follows;

Health Benefit:

This criterion covers both the amount of benefit and strength of evidence of benefit for heart health. The practical nutrient addition dosage compared to the amount required for health benefit was also taken into consideration.

Positive Consumer Awareness of Health Benefit and Acceptability in a Muesli Bar:

This covers three concepts that are each scored individually and then averaged to give an overall score; 1) **awareness** of the nutrient component, (2) **understanding** of benefit and (3) **acceptability** in a muesli bar, based on focus group findings (refer to chapter 5).

Processing and Stability:

This criterion assesses whether the ingredient is suitable for extrusion and the effect it will have on the ingredient's stability over storage time (refer to chapter 3).

Regulations:

Scoring was based on (1) allowable ingredients under the current FSANZ regulations and (2) health claims that can currently be made in the United States and levels of ingredients required to make nutrition content claim (NZ/Aust) or health claim (US). If ingredients were not currently allowed to be added to muesli bars in NZ, there may be a

case for approval in the future, therefore it was noted that this should also be considered when assigning a score.

Cost:

The cost score was based on an initial cost analysis that was conducted based on raw material prices and estimated quantities. The score was based on **cost / kg** added to nugget price so that dosage level is considered. It was noted that this was only a guide and price ranges rather than the lowest cost price of ingredient source should be considered since the most suitable form in terms of processing, functionality and sensory properties was yet to be determined.

Health benefit was considered to be the most important factor, as this was considered to be the main point of difference from other currently available extruded ingredients, and would form the basis for credibly marketing the finished products. Positive consumer awareness was also considered to be important for product adoption and hence commercial success. Processing and stability was moderately important as it is possible to apply unstable ingredients post extrusion processing. Regulations were also considered to be moderately important because legislation could dictate what nutrients may be included in a commercialised product. This latter factor was not intended to eliminate potential ingredients, particularly those permitted in overseas markets with export potential. Cost was a minor factor as it was appreciated that adding functional properties will increase cost.

Scoring

The researcher and most appropriate supervisor or company representative conducted the screening assessment. Each nutrient was given a numerical score on a scale from 0 to 10 based on appropriate research, with zero indicating a poor relationship between a factor and ingredient and ten indicating an excellent relationship between ingredient and factor. A brief justification was given for the allocated score. For the screening criteria 'Positive Consumer Awareness of Health Benefit and Acceptability in a Muesli Bar' there were three components, these were each scored out of ten and the three scores averaged to give an overall score. All other criteria were given single scores.

6.2 Screening Results and Discussion

Table 6.2 below outlines the overall screening results. A justification for the scores allocated may be found in **Appendix C2**.

Table 6.2: Summary of Screening Scores

	<i>Health Benefit</i>	<i>Consumer</i>	<i>Processing</i>	<i>Cost</i>	<i>Regulations</i>	<i>Total</i>	<i>Ranking</i>
WEIGHTING	0.45	0.25	0.15	0.05	0.10	1.00	
Omega-3	7.00	7.42	3.00	7.25	8.00	6.62	4
Monounsaturated	7.00	6.17	4.00	3.50	6.50	6.12	5
Soluble fibre	8.00	7.25	10.00	8.50	9.00	8.24	1
Plant Sterols	9.00	4.92	6.00	7.25	4.00	6.94	2
Soy Protein	8.00	4.50	9.00	5.25	4.50	6.79	3
Folate	5.00	3.83	5.00	2.50	1.50	4.23	6
Vitamin E	3.00	5.25	1.00	6.67	2.25	3.37	7

Table 6.2 shows that the order of ranking of the ingredients from most to least favorable was as follows; soluble fibre, plant sterols, soy protein, omega- 3, monounsaturated fatty acids, folate, vitamin E. As a consequence of the described screening exercise it was proposed that a high soluble fibre extruded ingredient be investigated. The justification for this decision and omission of other nutrients is discussed below.

Soluble Fibre

Soluble fibre was determined to be the most favourable ingredient by the screening process because it was deemed to have a high heart health benefit and consumers appeared to be well aware of the benefits of fibre. It was not excessively expensive and strong nutritional claims could be made for the product if it were exported to the USA. Finally, soluble fibre presented little or no processing difficulties, and in fact the soluble fibre could be increased under certain processing conditions (refer to chapter 3). The cholesterol lowering properties of soluble fibre have been well established and the FDA has approved a number of health claims in relation to soluble fibre and cholesterol reduction.

There are a number of potential sources of soluble dietary fibre including oat beta-glucan, barley beta-glucan, and psyllium. It was recommended that the research is concentrated on extruded oat products with high beta-glucan soluble fibre contents.

There are several reasons for investigating oat beta-glucan as the fibre source: a relatively low amount of oat beta-glucan compared with psyllium is required to make a heart health claim in the US (refer to chapter 4); oat bran is more widely recognised by consumers than psyllium; and finally oat products are cheaper than psyllium. Products containing 0.75g beta-glucan per serve qualify for a heart health claim in the US. Although, no such claim is currently approved under the FSANZ regulations (NZ/Aust), a claim of “good source of fibre” can be made providing the product contains 3g total dietary fibre per serve.

Plant Sterols

Plant sterols were ranked lower than soluble fibre mainly due to current low consumer acceptability and FSANZ regulations preventing use in products other than margarine. However, plant sterols were noted as having high potential for use in the future, should regulations allow. It was also thought that with the right marketing strategy, any negative consumer perception could be overcome.

Omega-3

It was decided that it would be impractical and counterproductive to include Omega-3 polyunsaturated fatty acids in the extruded ingredient. Omega-3 is extremely unstable and readily oxidises at high temperature. In addition trans-isomerisation of the fats in the extrusion process is also an issue. It was decided that it would be more practical to add encapsulated omega-3 fish oils to the bar itself, this way the encapsulant would remain intact and protect the oil from oxidation. Discussions with Roche (ingredient supplier) have indicated that cereal bars with added encapsulated omega-3 remained acceptable for a 12 month shelf life (Briscoe, Personal Communication, 2002).

However, the addition of fat (although beneficial fat) remains a concern in terms of meeting Heart Foundation Guidelines and FDA requirements. Moreover, consumers perception appear to be a problem as well because they appear to be more concerned about total fat content in products, rather than the constituent fats and so promoting a product on the basis of mono- and polyunsaturated fat content may prove to be difficult.

Soy Protein

Soy protein is a distinct possibility for making an extruded nugget. However, resistance was encountered from consumers (refer to chapter 5) due to an association with genetic modification and poor taste. Some concern about hormonal imbalances was also raised. The bar would need to be supplemented with a small amount of soy protein isolate in order to qualify for an FDA claim (based on 5g soy nuggets per 35g bar). Since Nice and Natural currently sources soy nuggets for use in protein bars, it seemed pointless to develop such a product.

Monounsaturated Fatty Acids

Monounsaturated fatty acids are less prone to oxidation than omega-3 polyunsaturated fatty acids. Monounsaturated fats (olive oil, avocado oil, sunola oil) may be used to coat the extruded nuggets prior to drying. However, once again there is concern about adding fat to the product unnecessarily.

Folate

It would be more practical to add folate to the bar than incorporate in an extruded nugget since some losses will occur in the extrusion process. Folate was ranked very low due to a lack of understanding of the heart health benefits of folate.

Vitamin E

Addition of vitamin E to an extruded ingredient is impractical due to the large processing losses. Vitamin E is highly sensitive to heat, light, oxygen and pro-oxidants such as metals (transferred in trace amounts by extruder screws). In addition, the heart health benefits of vitamin E are not as well substantiated or recognised by consumers.

6.3 Conclusion

Probability screening was conducted to determine which nutrients should be incorporated into an extruded ingredient. Nutrients were screened against 5 criteria (Health Benefit, Positive Consumer Awareness of Health Benefit and Acceptability in a Muesli Bar, Processing and Stability, Regulations and Cost). The screening results

scored nutrients from most to least favorable in the following order: soluble fibre, plant sterols, soy protein, omega- 3, monounsaturated fatty acids, folate, vitamin E.

It was decided that experimental work in this project should focus on incorporating soluble fibre from oats into an extruded ingredient. A justification for this decision has been given.

7. EXTRUSION LITERATURE REVIEW

7.1 Extrusion Process

Extrusion cooking is a continuous thermo-mechanical process. It is a “process where foods are forced to flow under one or several conditions of mixing, heating and shear, through a die that forms and/or puff-dries the ingredients” (Rossen and Miller, 1973, cited in Riaz, 2001).

The two major types of cooker extruders are single-screw extruders and twin-screw extruders. Extruders can be further classified as wet or dry extruders depending on whether or not water or steam is added; continuous or interrupted flight extruders. Twin-screw extruders are classified as co-rotating or counter-rotating depending on the relative direction of screw rotation. The extruder used in this research was a twin-screw co-rotating extruder. However a number of common principles apply to all.

An extruder typically consists of a feed delivery system, a pre-conditioner, extruder barrel, die and knife. The feed system is designed to continuously feed raw materials to the pre-conditioner or extruder barrel (if there is no pre-conditioner) using conveying screws. The raw material level can be maintained within desired limits using high and low sensors. The feed hopper is also designed to prevent bridging of powders which lead to blockages and interruption to the supply of raw material, constant flow of raw material is important in order to achieve a consistent product (Riaz, 2001).

Pre-conditioners may be used as a means of pre-mixing the feed material, often water or steam is also added. This is of benefit to high moisture extrusions, and product quality can be greatly improved (Riaz, 2001). In addition, the use of a pre-conditioner dramatically improves the life of extruder components. The preconditioned material is then fed to the extruder barrel. The extruder barrel section comprises a stationary barrel housing which is typically steam jacketed, with individual heating elements; a twin-screw extruder has two rotating shafts on which screws of variable geometry (pitch, flight, reverse screws, mixing paddles) are arranged in various configurations. The screws act as positive displacement pumps to convey the material through the barrel

whilst shearing and mixing the dough; a die through which the material is forced and this is located at the end of the extrusion barrel; and a knife attachment to cut the product to the desired size.

The extruder barrel generally consists of three processing zones; feeding zone, kneading zone, and the final cooking zone (Mercier *et. al*, 1989 in Riaz 2001). The flight and pitch of the screws decrease along the length of the shaft. The feeding zone has deep flight to receive the feed. Material is then conveyed to the kneading zone. The kneading zone has shallower flight and shorter pitch to aid mixing and achieve a higher degree of fill. Water or steam may be added to improve heat transfer and aid dough development. In this zone compression, mild shear and heat are applied. As the extrudate moves through this zone it loses granular definition and becomes a compact, cohesive dough that exhibits a rubbery texture. It then enters the final cooking zone in which the flights are shallow and short pitched. The material is compressed and pumped to the die. Shear and temperature are at a maximum in this zone. The product expands as it is forced through the die and subjected to a sudden pressure drop which causes vaporisation to occur (Riaz, 2001).

7.2 Raw Materials

Extruded foods are produced from a diverse range of raw materials. Different materials perform various functions in the formation and stabilization of extruded products, the nutritional quality and the sensory acceptability of foods. Ingredients interact in the extrusion process and affect the transformations that take place. It is therefore important to understand the role of each ingredient in the raw material formulation and the effect it will have on the extruded product. The Guy Classification System (Guy, 2001) groups ingredients based on their functional role. The seven groups cited are outlined below. Although some of the minor ingredient functions were not required in the new extruded ingredient developed in this project, they have been included in this section in order to provide a complete overview.

7.2.1. Group 1: Structure Forming Materials

The final structure of an extruded product (extrudate) is determined by the raw materials that it is produced from and the temperature, pressure and moisture conditions in the barrel prior to being forced through the die. Generally, the raw materials form a fluid biopolymer melt with water vapour bubbles dispersed throughout so that the mix resembles a foam. The biopolymer melt forms cell walls around the gas bubbles. Ideally this melt must flow easily in the extruder barrel so that bubbles can expand until they burst when they exit the die, as superheated water is evaporated at atmospheric pressure. As a result of this evaporation the temperature in the melt drops rapidly and the viscosity increases due to the moisture loss and the cellular structure becomes rigid, forming a glassy state.

Starch or protein can be used to form the structure. Most extruded breakfast cereals and snack food products are starch based and the ingredient developed in this project was no exception. Starch polymers are good structure forming materials. Since starch is the most influential raw material in extrusion, this review will focus on this component in greatest detail.

Starch

The most important processes related to starch are gelatinisation and dextrinisation (Guy, 2001). The transformation that starch undergoes during extrusion is different from the typical gelatinisation that occurs in a high moisture non shearing system. Under extrusion processing conditions, namely low moisture and high temperature, starch undergoes a process called dextrinisation (Campanella and Shah, 1997).

The transformation is dependent on;

1. Physical Form

Starch granules, composed of small aggregates vary widely in size and shape depending on the plant source from which they are derived. The physical properties of the starch granules, i.e., size, shape and composition affect the behaviour of the starch in the extrusion process. Table 7.1 below outlines the different size, shape and composition of some of the commonly used starches.

Table 7.1: Size, shape and composition of some commonly used starches (BeMiller and Whistler, 1996; Campanella and Shah, 1997)

<i>Starch Type</i>	<i>Wheat</i>	<i>Rice</i>	<i>Maize</i>	<i>Oat</i>
Size (major axis, μm)	Medium – Large 2 -55	Very small 1.5 - 9	Medium 2 - 30	small
Shape	Lenticular		Polygonal	
Composition (% amylose)	20 -27			20 -27
Energy Requirements for extrusion	Medium - Low	High temperature	Medium – High	High

The following review will focus on oat and maize because these are the starches used in this project.

Size: small granules heat to the critical melting point more quickly (due to a shorter distance for the heat to travel) and soften more rapidly in the extruder (Guy, 2001). Oat granules are of small size, this would generally require lower extrusion temperatures, but due to the high lipid content of oats, higher temperatures are needed to achieve expansion (Campanella and Shah, 1997). Medium size maize granules require medium to high energy input, but expand well.

Shape: the shape and surface properties of the starch granules has an effect on the mechanical energy. For example, smooth globular or lenticular granules of wheat create less friction than the polygonal starch granules of maize (as used in the development of this ingredient). At high screw speeds maize starch creates almost twice as much specific mechanical energy (energy applied through heating + energy created by frictional forces within the extruder per kg of product extruded) as wheat starch. Higher specific mechanical energy results in greater expansion. Since an expanded product was desired, maize starch was selected as an appropriate starch source for the new extruded ingredient.

2. Composition

Starch granules are composed of two glucan polymers; amylose, an essentially linear molecule with a double helix crystalline structure made up of 100-1000 glucose units linked by α -(1-4) bonds and amylopectin, a highly branched molecule with an amorphous polymeric structure, made up of linear regions of α -(1-4) linked glucose units and branched α -(1-6) linkages. In addition there are trace amounts of lipid (0.5-1%) distributed throughout the starch structure and protein adhering to the surface. Amylose/amylopectin ratios vary between different cereals and between different varieties of the same type of cereal. Typically amylose content is approximately 20-30%, high amylose varieties may contain up to 70% amylose and waxy varieties are close to 100% amylopectin (Campanella and Shah, 1997). Waxy, standard and high amylose starches were investigated in the development of this ingredient.

Waxy corn starches have been shown to have better diametral expansion than high amylose corn starches (Kokini *et al.*, 1992). Harper and Tribelhorn (1992) reported that products produced using high amylose corn meal had a fine structure, with small consistently sized cells. Standard corn meal (approx. 72% amylopectin) produced products that were brittle, had a low density and irregular shaped cells, similar physical characteristics were obtained using waxy (approx. 100% amylopectin) corn meal.

Expansion of extrudates is related to the rheological properties of the melt (Kokini *et al.*, 1992). Expansion is reduced with increased melt viscosity (Kokini *et al.*, 1992) due to slower bubble growth, and is improved by processing conditions that reduce melt viscosity such as high screw speed. However, sufficient viscosity is required to prevent collapse after expansion.

Cereal Flours

Most extruded products are made using flours since they are the cheapest form of raw material. Flours vary in their physical nature and thus in their performance in the extruder. Flours may be classified as 'soft' or 'hard' flours.

Oat flour, which was used as a major component in the formulation of the new extruded ingredient, is classed as a soft flour. Soft flours are derived from grains in which the starch and protein are only loosely bound, and the endosperm is easily broken down

(e.g. wheat, rye, barley, oat and portions of maize from the inner endosperm). Soft flours produce less mechanical energy and therefore take longer to form the melt than hard flours. As a consequence the starch doesn't melt until it is much further along the extrusion barrel than would be the case for a 'hard' flour. This means that there is less time in the final shearing sections of the extruder barrel to produce the desired transformations to the starch granules and this in turn results in low expansion in the extrudate.

Oat flour was selected as an ingredient for the new extruded ingredient predominantly for its nutritional contribution to dietary fibre and β -glucan content. However, because it is a 'soft' flour it was expected to produce low expansion in the extrudate which was undesirable.

Hard flours are derived from grains in which there is strong bonding between the starch granules and the protein layers (e.g. rice, hard wheat, durum wheat, vitreous flint maize, and some varieties of barley). These particles produce more mechanical energy, but large particles require greater energy to break down. Small particles will melt quickly and have a longer time to develop in the shearing zone, creating a high level of expansion (Guy, 2001).

Protein

Although the ingredient developed in this project was starch based, proteins can be used as structure forming materials at high concentrations (>40% w/w) (Guy, 2001). Globular proteins derived from oilseeds (such as soya, rape, sunflower and cottonseed) and gliadin/glutenin mixtures from wheat flour have been shown to form a continuous structure in extrusion processing.

7.2.2. Group 2: Dispersed-Phase Filling Materials

Within the continuous phase (consisting of starch or protein) are other dispersed phases. The dispersed phase may consist of proteins (present at low concentrations) or fibres such as cellulose or bran. In the current project oat bran functioned as a dispersed-phase filling material. The properties of this dispersed phase (size and shape) depend on original particle size and their resistance to shear.

Dispersed phase particles have two major effects on the structure of extruded products;

1. Decrease expansion of the extrudate by disrupting the cell walls of the continuous phase
2. Reduce the die swell effect due to the fact that they decrease the elasticity of the continuous phase.

Fibre

Fibrous materials including hemicellulose, cellulose, lignin derived from the bran and husks of grains and seeds remain stable and are not reduced in size during extrusion. Bran has a significant effect on product texture, expansion and shape at levels above 2-3% (Guy, 1994). The effect of dietary fibre on expansion has been described previously in Chapter 3.

7.2.3. Group 3: Ingredients that act as plasticisers and lubricants

Water

Water functions as a plasticiser. Addition of water plasticises the dry material and transforms it to a plastic fluid. Excess water decreases the dissipation of mechanical energy and decreases the heat input. In low moisture systems frictional forces and mechanical energy heat the dough mass up to 150°C without external heating (Frame, 1994). Generally water or steam is added to the dry ingredients by injecting it into the feed zone of the barrel (Riaz, 2001). In the development of this ingredient water was injected in the first barrel of the extruder.

Fats and Oils

Fats and oils function as a lubricant, fats melt above 40°C and act as liquid oils. They mix with other materials and are dispersed in the continuous phase in fine droplets (<1-5µm). These materials lubricate the particles in the dough and the surfaces of the screws and barrel and reduce particle–particle and particle-screw frictional forces. Lubrication reduces the shear acting on starch particles, therefore starch particles take longer to disperse and oil contents greater than 2% may result in cooked products with no expansion. This is an issue when extruding oat flour as oil contents are approximately 8%. However, above 30% moisture the effect is reduced as free water acts to swell starch and some expansion may be achieved (Guy, 2001).

7.2.4. Group 4: Soluble Solids

Sugars and Salt

Soluble materials dissolve in the unbound water in the continuous phase. The most common forms of soluble solids added are sugars and salt. The effect of these materials is dependent on concentration and their chemical interaction with starch and protein polymers. The melt viscosity may be decreased indirectly if these materials replace starch without a decrease in water. The diluted starch will have a reduced energy input and hence temperature which would result in a less expanded product (Guy, 2001). Soluble solids were omitted from the new ingredient developed in this project in order to maximise the starch content and to simplify the formulation system.

7.2.5. Group 5: Nucleating Substances

Nucleating substances increase the number of bubbles formed in the extrusion melt. Nucleation has also been shown to change the nature of expansion from anisotropic to isotropic. The nucleation process requires particles that remain insoluble and provide surfaces that reduce energy for individual bubble formation. Originally bran was used as a nucleating agent, since it was known that bran particles remain intact during extrusion. However, calcium carbonate and insoluble calcium phosphate, both very fine powders were later found to work well at much lower concentrations than bran. Consequently, it was expected that the oat bran would possibly act as a nucleating substance even though it was primarily added for its nutritional content.

7.2.6. Group 6: Colouring Substances

Colour may be formed by addition of precursors for maillard reactions which occur between reducing sugars and amine groups on amino acids peptides and proteins. Milk powder or whey are commonly used to provide these substrates. The formation of polymeric phenolic compounds can also lead to the development of pale red-brown colours, these darken with increased heating times. Some colour may be present because of the raw materials used in the formulation. However cereal grains are often only lightly coloured and their pigments heat labile. Synthetic, heat stable up to a maximum of 150- 160°C are often added as colourants in extruded products (Guy, 2001). Colour was not an important consideration in this project, however precursors for maillard browning or synthetic colouring may be used if colour variety is required in the future.

7.2.7. Group 7: Flavouring Substances

Flavour may be formed by the addition of precursors for thermal reactions or flavouring substances may be applied post extrusion. Flavours are not generally added to the extruder, due to the losses of volatiles under extrusion conditions. (Maga, 1989, cited in Guy, 2001). The ingredient developed was not intended to be highly flavoured and provided the ingredient was free from objectionable off-flavours, flavour was not considered to be a major issue. However, once the product is commercialised it may be necessary to flavour the product if consumer response to the resulting muesli bars is poor.

For this project, it was appreciated that the ingredients added for nutritional functionality (oat flour and oat bran) may not produce a suitable product structure and other structure forming materials (e.g. starch) would need to be incorporated into the feed formulation. Ideally the nutrients included in the 'functional bubble', extruded ingredient would be enhanced nutritionally and/or texturally.

7.3 Extrusion Process Variables

Extruded product characteristics are achieved by optimising and controlling the machine process variables. The main process variables are:

- Moisture content
- Barrel and die temperature
- Feed rate and screw speed
- Screw design and configuration

7.3.1. Moisture Content

Moisture content is one of the most influential processing variables controlling the expansion and texture of extruded products as it affects melt viscosity and melt temperature and as a consequence the degree of expansion of the extrudate (Lawton *et al.*, 1972, Fletcher *et al.*, 1985, van Lengerich, 1990 cited in Li, 1998; Mercier and Feillet, 1975 cited in Kokini *et al.*, 1992). Therefore water feed rate was an important processing parameter that needed to be considered in this research.

Chen *et al* (1991, cited in Murray, 2001) found that moisture had one of the most important effects on sensory characteristics of extrudates including the parameters crispness, hardness and appearance (Chiou, 1986, Pan *et al.*, 1987, Wu *et al.*, 1989, Chen *et al.*, 1990, cited in Kokini *et al.*, 1992). Decreasing the moisture content has been shown to increase expansion of rice extrudates (Faller and Heymann, 1996; and Gomez and Aguilera, 1984, cited in Murray, 2001) and decrease sensory panellists perception of the hardness of extrudates.

Maximum expansion of corn starch was reported at a moisture content of 14% (Chinnaswamy and Hanna, 1988, cited in Li, 1998). Expansion increased with decreasing moisture content (from 30% dwb to 14% dwb) and dramatically increased with a moisture less than 14%.

The effect of moisture on expansion may be explained by the effect on melt viscosity (Kokini *et al.*, 1992). Water provides lubrication and decreases the viscosity of the melt. A decrease in viscosity reduces the pressure in the die (Kokini *et al.*, 1992), thereby decreasing the pressure drop and hence expansion.

Moisture also influences the colour and flavour of extrudates. Extrudates produced under conditions of low moisture and high temperature promote Maillard browning and result in a characteristic brown colour. (Bredie *et al.*, 1998, Faller & Haymann, 1996, cited in Murray, 2001).

7.3.2. Barrel and Die Temperature

The temperature of the melt is influenced by the conductive and convective heating of the extruder barrel, the mechanical heat generated in the barrel by the shear forces, and the temperature of the die (Frame, 1994). The amount of heat generated by shear force is influenced by a number of extruder operational characteristics including the screw profile, screw speed, moisture and oil content of the feed (determines degree of lubrication). At low moisture (<20%) heating may be achieved via frictional forces only (Frame, 1994).

The melt temperature (and also barrel and die temperature) has a large effect on the rheological properties of the melt and the expansion characteristics of resultant products

(Li, 1998). Increasing the melt temperature has been shown to increase the degree of starch gelatinisation and produce products with higher expansion. Except at very high temperatures, where a decrease in viscosity of the melt and product expansion has been shown to occur, presumably due to starch degradation (Chiang and Johnson, 1977, Chinnaswamy and Hanna, 1987, Colonna *et al.*, 1984 and Davidson *et al.*, 1984a,b cited in Li, 1998).

The main reactions governing extrudate quality at temperatures below 160°C were gelatinisation and bond cleavage of starch. Above 160°C caramelisation rapidly increases resulting in a decreased expansion ratio and slightly improved crispness (Kokini *et al.*, 1991).

7.3.3. Feed Rate and Screw Speed

Consistent addition of feed to the extruder is important to ensure a stable and uniform product (Guy, 2001). The feed rate and screw speed determine the residence time and degree of fill within the extruder barrel. Controlling these speeds ensures that the extruder is not starved (emptied) or flooded (Guy, 2001). An increase in the feed rate or decrease in screw speed increases the degree of fill. According to van Lengerich (1990, cited in Li, 1998), a lower degree of fill results in increased specific mechanical energy. The viscosity of starch melts has been shown to be lower with a lower degree of fill (Li, 1998). Chinnaswamy and Hanna (1988, cited in Li, 1998) showed that the optimum expansion was related to a maximum value of $\Delta P/(\mu_a)_d$ where ΔP is defined as the pressure difference and $(\mu_a)_d$ is the apparent viscosity of the melt at the die. Lower expansion was found for higher and lower values of $\Delta P/(\mu_a)_d$.

Harper (1981) suggests that screw speed has a minor effect on extrudate properties. However, Hseish & others (1990, cited in Murray, 2001) found increasing screw speed to increase product expansion.

The mean residence time decreases with increasing feed rate. Increasing the feed rate resulted in a decrease in crispness and increases in the water solubility index (soluble material as a percentage of the dry sample weight) and the sectional expansion ratio (the ratio of product cross-sectional diameter to the diameter of the die). Operating at a

minimum feed rate and a screw speed of 120-240rpm resulted in minimum water solubility and shearing force (Pan *et al.*, 1992).

7.3.4. Screw Design and Configuration

The screw profile (screw design and configuration) affects the shear forces within the extruder (Frame, 1994) and impacts on the extruder performance and product properties. The screw configuration used is generally a series of repeated mixing and conveying screw elements. Conveying screw elements vary in pitch and depth, conveying screws with shallow flights increase the amount of shear. The high shear enhances internal mixing and the dissipation of mechanical energy is large, hence temperature increases rapidly. Since the degree of expansion is directly related to temperature, a shallow flight results in maximum expansion (Harper, 1981).

Mixing elements (such as paddles, reverse pitch screws) cause a restriction of product flow and create back pressure. Sokhey *et al.* (1994, cited in Li, 1998) have shown that a screw configuration without mixing elements resulted in higher expansion in single-screw extrusion of corn starch. Whereas, Kirby *et al.* (1988, cited in Li, 1998) showed that a well expanded product (produced from maize grits) could not be achieved without mixing paddles in a twin-screw extruder.

Extrusion processing variables are interrelated. Literature suggests that a screw profile that utilises conveying screws with shallow flight is favourable for an expanded product. The use of mixing elements should be kept to a minimum and used only to allow sufficient mixing. The screw profile utilised in this research was limited by the screw elements available and was based on the screw profile used by Li (1998) for expanded corn extrudates on the same pilot plant extruder. Extruder settings that contribute to a higher amount of work and pressure in the extruder result in higher expansion.

Expansion tends to increase with increasing barrel and die temperatures up to 160°C, decreasing water content between 30% and 14% and increasing screw speed.

7.4 Extrusion and Oats

Oat was selected as the main raw material in the screening process (refer to chapter 6) therefore this section is dedicated to oat extrusion. The information that is of greatest interest for this project is: the effect of extrusion on the dietary fibre and β -glucan content of oats and the physical and sensory properties of oats. The dietary fibre and β -glucan contents are related to the heart health benefits of oats and the physical and sensory properties are important for the consumer acceptability of the final product. There is only limited information available on oat extrusion, therefore the results of this research should be of interest.

Beta-glucan is present in the endosperm and endosperm cell walls; β -glucan comprises approximately 75% of endosperm cell walls (Miller *et al.*, 1995 cited in Wood and Beer, 1998). The amount of β -glucan in the various oat ingredients commercially available depends on the oat cultivar, environmental conditions and milling methods used. Beta-glucan contents reported for oat flour have ranged from 0.6% dry weight basis (dwb) (Knuckles *et al.*, 1992 cited in Wood and Beer, 1998) up to 2.3%dwb. Beta-glucan contents of oat bran have ranged from 5.8-8.9%dwb up to 21.2% dwb. The β -glucan level may be enhanced depending on the milling method used.

To produce a puffed oat based ready-to-eat cereal by extrusion is difficult, due to the high fat and soluble fibre content in oats (Chang and Sosulki, 1985 cited in Liu *et al.*, 2000). However, Liu *et al.* (2000) suggest that it is possible to obtain a puffed oat-corn snack with satisfactory sensory properties by blending corn flour with oat flour.

It is difficult to draw direct comparisons between extrusion studies and generalise the effect of individual processing variables. Extrusion variables are interrelated, and processing using different extruders may yield different results (Björck and Asp, 1983). Therefore, the results of several studies on oats and oat products will be individually discussed.

7.4.1. Effect of Extrusion on Physical and Sensory Properties

Liu *et al.*, (2000) used a co-rotating intermeshing twin-screw extruder to investigate the effect of different oat flour level, screw speed and moisture on the extrudates properties of an oat corn puff. The results are summarised in Tables 7.2 and 7.3 below.

Table 7.2: Effect of Oat Flour, Moisture and Screw Speed on Physical Properties and Colour (Liu *et al.*, 2000)

	<i>Physical Properties</i>
↑ Oat Flour	↑ bulk density ↓ specific length (length of extrudate per gram) ↓ expansion ratio* Effect on expansion ratio dependent on oat flour level 100% oat flour – no significant effect on bulk density, specific length and expansion ratio.
↑ Feed Moisture	Bulk density lowest at medium moisture level. Minimum bulk density at 70% oat flour and 19.5% moisture. ↓ specific length
↑ Screw Speed	↓ bulk density ↑ specific length ↑ expansion ratio

*Addition of 15% corn flour significantly increased expansion ratio, no significant difference in expansion between 15 and 30% added corn flour.

Singh and Smith (1997) investigated the effect of temperature and moisture on oat flour extrusions using a co-rotating intermeshing twin-screw extruder. They found that the effect of moisture was temperature dependent. At 125°C increasing moisture decreased expansion but at higher temperatures expansion increased.

Hsieh *et al.* (1989) found that addition of oat fibre (up to 20%) to corn meal using a co-rotating twin-screw extruder resulted in similar effects on the physical properties to those shown by Liu *et al.* (2000) for oat/corn flour, except in this case axial expansion was increased.

Table 7.3: Effect of Oat Flour, Moisture and Screw Speed on Texture and Sensory Properties (Liu *et al.*, 2000)

	<i>Texture</i>	<i>Sensory</i>
Increased Oat Flour	↓ springiness, gumminess and chewiness ↑ fracturability and hardness (maximum at 85% oat flour and 21% moisture)	↑ negative appearance attributes (roughness, compact, dry surface, curving and irregular)
Increased Feed Moisture	↑ springiness, gumminess and chewiness ↑ fracturability and hardness (possibly due to decreased expansion) ↓ cohesiveness	Affected attributes crunchiness, coarseness, chewiness and hardness (associated with ungelatinised or unexpanded samples)
Increased Screw Speed	↓ springiness and chewiness ↑ gumminess ↓ fracturability and hardness (possibly due to increased product temperature which leads to increased expansion) ↑ cohesiveness	↑ corn related flavours Affected attributes associated with well expanded product (open cell, crispness and shiny)

Contrary to the findings of Liu *et al.* (2000), Hseih *et al.* (1989) found that increasing the screw speed resulted in higher breaking forces for corn meal extrudates with added oat fibre or wheat fibre due to the increased bulk density of the extrudates. As screw speed was increased from 200 to 300rpm the die pressure decreased and hence the extrudate encountered less resistance at the die and exited with a higher linear velocity. This resulted in greater axial expansion and less radial expansion, the net result an extrudate with higher bulk density and breaking force.

Increasing the fibre content also resulted in an increase in breaking force due to increased bulk density of extrudates. Similar results were reported by Anderson *et al.*, (1981, cited in Hseih *et al.*, 1989) and Liu *et al.* (2000).

7.4.2. Effect of Extrusion on Dietary Fibre

The soluble dietary fibre content of oats is of greatest interest due to its cholesterol lowering properties. The component in oats thought to be responsible for its cholesterol lowering properties is β -glucan; β -glucan is also found in barley (and yeast), therefore barley will also be discussed when there is insufficient information available on oats. The effect of extrusion on dietary fibre solubility has been described in chapter 3, this is an expansion of the previous section.

The effect of screw speed on dietary fibre contents and solubility of oats and other cereals has been investigated by Gualberto *et al.* (1997) and Wang and Klopfenstein (1993).

Extrusion increased the soluble fibre content of oats by approximately 32% and reduced insoluble fibre content (between 14.3% and 17.7%) (Gualberto *et al.*, 1997). However, the increase in soluble fibre and decrease in insoluble fibre was lower at higher screw speeds. A similar pattern was found for rice bran, and no significant losses found for wheat bran. This is in contrast to the suggestions of previous authors cited in Gualberto *et al.* (1997) that a decrease in insoluble fibre may be caused by high shear stress caused by high screw speed.

Wang and Klopfenstein (1993) reported non-linear results for the effect of screw speed on dietary fibre and β -glucan contents. TDF, SDF and β -glucan contents were optimised at a screw speed of 300rpm and lower contents were found at higher and lower screw speeds.

Gualberto *et al.* (1997) proposed several possible mechanisms that influence the dietary fibre composition and suggests that several of these mechanisms may act simultaneously with some increasing and other decreasing the insoluble fibre content;

1. Shear stress (produced by higher screw speeds) causes chemical bond breakage and results in smaller sized particles that are soluble.
2. Lower screw speeds result in higher pressure within the extruder due to a higher degree of screw fill. The higher pressure may increase solubility.
3. Resistant starch fractions may be formed leading to increased dietary fibre
4. Lipid-polysaccharide complexes may have been formed; these complexes could not be cleaved by alpha-amylase or amyloglucosidase nor extracted by hexane and were therefore analysed as insoluble fibre.

7.4.3. Resistant Starch

Resistant starch (RS) has been defined as “the sum of starch and products of starch degradation not absorbed in the small intestine of healthy individuals” (EURESTA, 1992 cited in Brumovsky and Thompson, 2001). The resistant starch fraction passes through into the large intestine where it is fermented by colonic microflora to short-

chain fatty acids (Unlu and Faller, 1998; Cummings *et al.*, 1986, Englest and MacFarlane 1986, Mathers 1982, Schulze, 1992 cited in Brumovsky and Thompson, 2001). The nutritional significance of resistant starch is that it may exert a similar physiological effect to dietary fibre (Berry, 1986, cited in Unlu and Faller, 1998; Biladeris, 1991, Björck, 1996, Brown, 1996 cited in Brumovsky and Thompson, 2001), which has been shown to reduce the risk of coronary heart disease. Since the resistant starch content of foods can be altered through processing, it is of significant interest. Extrusion cooking is particularly conducive to RS formation (Unlu and Faller, 1998).

There are three types of resistant starch: Physically inaccessible starch (RS1), resistant starch granules (RS2) and retrograded starch (RS3) (Englest *et al.*, 1992 cited in Unlu and Faller, 1998). Food processing (including extrusion processing) generally destroys RS1 and RS2, but may produce retrograded starch (RS3) (Berry, 1986, Berry *et al.*, 1988, Sievert and Pomeranz, 1990, cited in Unlu and Faller, 1991).

Retrogradation is the process of aggregation and recrystallisation of starch that occurs during cooking and storage. Retrogradation involves both starch constituents (amylose and amylopectin), however, retrograded starch formed during processing is generally accepted to be associated with the amylose fraction of the starch molecule. Amylopectin retrogradation is much slower and occurs during storage.

There are a number of factors that effect amylose retrogradation, these factors include: polymer chain length (Clark *et al.*, 1989, Eerlingen *et al.*, 1993b cited in Unlu and Faller, 1998); the rate of retrogradation increases with increasing chain length and is retarded by side chains, presence of lipids and sugars (Szczodrak and Pomeranz, 1992, Eerlingen *et al.*, 1994, cited in Unlu and Faller, 1998) and heating time and temperature (Eerlingen *et al.*, 1993a cited in Unlu and Faller, 1998).

Unlu and Faller (1998) found that dietary fibre plus resistant starch contents of extruded samples increased with increasing amounts of high amylose corn starch and increasing citric acid addition, presumed to be due to the formation of resistant starch, but decreased at higher screw speeds. Addition of high amylose corn starch increased the amylose content which resulted in more retrograded amylose (resistant starch). The addition of citric acid increased resistant starch formation, possibly due to acid

hydrolysis, a process whereby the starch polymers amylose and amylopectin, are reduced in size. Smaller amylose molecules may have lead to greater amylose-amylose self associations (Unlu and Faller, 1998). Lower TDF + RS values found at higher screw speeds may have been due to the shorter residence time within the extruder being insufficient for aggregation of linear amylose chains.

7.5 Conclusion

The principles of extrusion and components of an extruder have been outlined. The functional role of ingredients in the feed formulation have been described. Starch or protein is required to form the structure of extrudates, in this research starch shall be used. The extrudate structure is dependent on the starch composition and physical properties. Fibres and proteins at low concentrations are dispersed in the continuous starch phase. Water functions as a plasticiser and fats and oils act as a lubricant. Utilisation of feed materials with high oil contents (such as oat flour used in this research) may result in a product with little or no expansion. Soluble solids, nucleating substances, colours and flavourings were also discussed. Colour and flavour may be developed via maillard reactions.

The main extrusion process variables were discussed. These variables were; moisture content, barrel and die temperature, feed rate, screw speed, screw design and configuration. The effect of these variables on expansion may be explained by the effect of the variables on the rheological properties of the melt. Decreasing moisture, increasing barrel and die temperatures, decreasing feed rate, increasing screw speed and the use of shallow flighted screws and minimal paddles all tend to favour expansion.

Oat ingredients were selected as the major raw material for the new extruded product because of its ability to reduce cholesterol levels. Oat flour contains relatively low levels of beta-glucan and oat bran contains higher levels. The beta-glucan content may be concentrated by careful selection of milling method, one that includes the endosperm and endosperm cell walls and excludes other fractions. Oat bran concentrates with β -glucan contents up to 21% are commercially available.

Extrusion has been shown to increase the soluble fibre in oats at the expense of insoluble fibre. The effect is dependent on screw speed. The increases in fibre content may be due to resistant starch formation. Resistant starch formation within the extruder involves amylose and therefore can be maximised using high amylose starch. Starch hydrolysis may assist amylose-amylose associations involved in resistant starch formation.

8. EXTRUSION EXPERIMENT

This research examines the effect of extrusion processing and raw materials on the nutritional and physical properties of an extruded oat product. The primary raw material of interest in this study is oats. Oats were selected in the initial screening stages of the product development process (see Chapter 6) where screening was based on the following factors: purported heart health benefit of dietary fibre, the effect of extrusion processing on the nutrient content and benefit, consumer acceptability and appeal, market potential and regulatory allowances and claims.

Oats contain soluble fibre (β -glucan), a soluble nutrient that is recognised for its ability to lower cholesterol and hence help with cardiovascular disease (refer to Chapter 3). Whilst a heart health claim can be made for β -glucan in the United States, this is not possible in New Zealand. Here the only type of claim permitted is a nutrient content statement for dietary fibre. Literature suggests that the dietary fibre content of a food or raw material may be increased through extrusion processing. Therefore, an indication of the effect of extrusion processing on both dietary fibre content and β -glucan content is of primary interest in this study. As the extruded ingredient is intended for use in cereal bars, the effect that extrusion has on the degree of expansion and hardness, and hence its sensory properties is also of interest.

8.1 Materials

Oat Flour and Bran

Oat flour & oat bran were obtained from Harraways and Sons Ltd (New Zealand). The nominal composition of the flour and bran are shown in Table 8.1 below.

Table 8.1: Specification for Oat Flour and Oat Bran

	<i>Oat Flour</i>	<i>Oat Bran</i>
Moisture (%)	10	12
Fat (%)	4 - 6	5.1
Fibre (%)	3	12.7

Full specifications for oat flour and oat bran are shown in **Appendix D-1** and **D-2** respectively.

Naked Oats

Naked Oats were obtained from Crop and Food Research in Palmerston North.

Corn Grits

Corn Grits were obtained from Corson Grain Ltd. (Gisborne, New Zealand).

Flaxseed Fibre

Nutri-flax flaxseed fibre was obtained from Functional Wholefoods (formerly Waihi Bush).

Starch

Starches of various amylose and amylopectin ratios were obtained from National Starch and Chemical NZ and Penfords New Zealand. The starches used were recommended for an extrusion application by staff at Crop and Food in Palmerston North (Harding, R., Personal Communication, 2002) and the starch supplier (Craven, R., Personal Communication, 2002).

Three starches were used;

1. Thermflo (National Starch and Chemical NZ), a modified waxy maize starch (subsequently referred to as 'Waxy')
2. Hylon[®] VII (National Starch and Chemical NZ), an unmodified high amylose corn starch which contained 70% amylose. (subsequently referred to as 'HA')
3. Avon (Penfords NZ), a standard unmodified maize starch containing 26% amylose and 74% amylopectin (subsequently referred to as 'Std')

The moisture content of the starches was approximately 11%.

Specifications for these starches may be found in **Appendix D-3 – D-5** respectively.

Citric Acid

Citric acid was obtained from Hawkins Watts (New Zealand). Citric acid was used to hydrolyse the starch in an attempt to increase resistant starch formation within the extruder as shown by Unlu and Faller (1998).

Enzyme

A pullulanase debranching enzyme, Promozyme[®] 400L was obtained from Novo Nordisk A/S (Denmark). A specification may be found in **Appendix D-6**.

8.2 Extrusion

8.2.1. Formulation Preparation

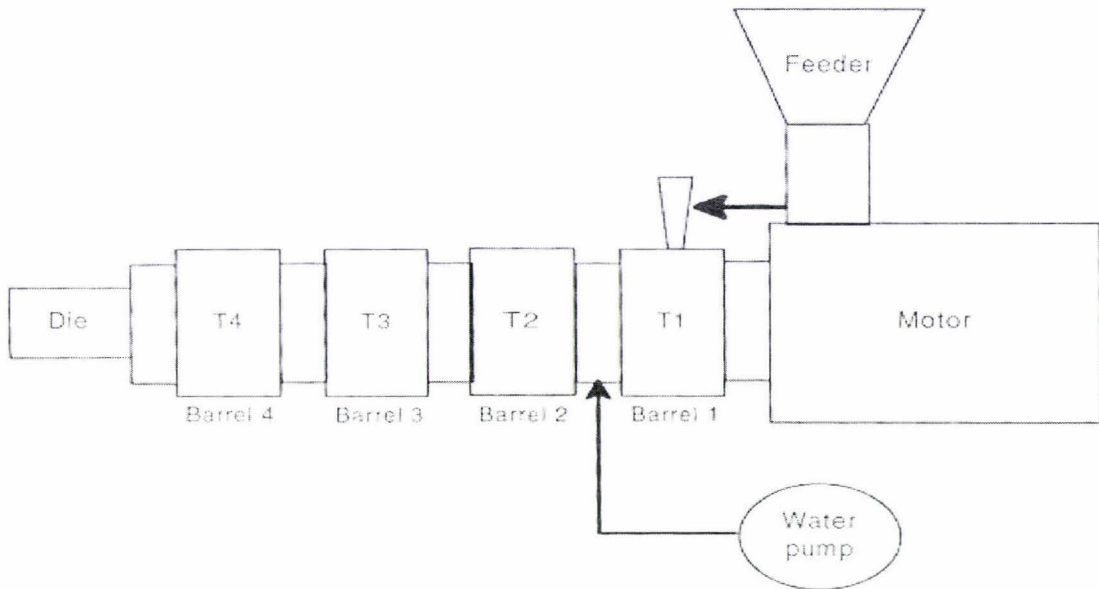
Formulations were weighed (accuracy = 0.1g) into large plastic bags according to formulae shown in Table 8.2 and Table 8.3 for preliminary (sighter) trials and factorial design experiments respectively. A 2kg quantity of each formulation was extruded. Formulations were blended by vigorously shaking contents in the plastic bag for 1-2 minutes prior to extrusion.

8.2.2. Extruder

A twin-screw, co-rotating extruder, Clextral BC21 (Clextral, France) was used in this research. A schematic diagram of the set-up used in the experimental work is shown below in Figure 8.1.

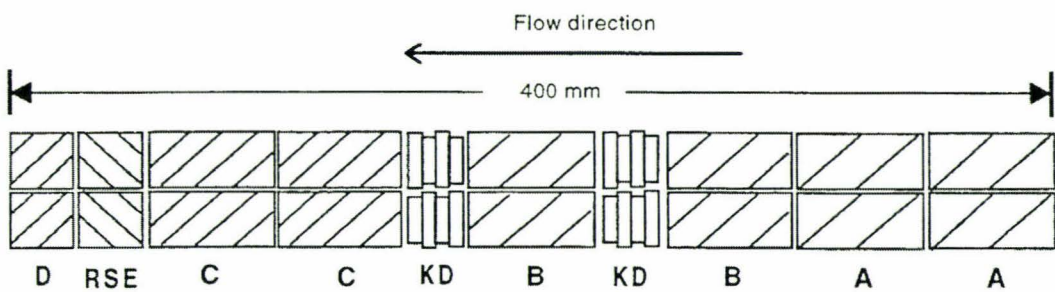
The extruder barrel has four sections. Each section is equipped with an independent temperature control unit. Dry raw materials were fed into the extruder by a volumetric feeder and water was directly injected into the mixing section of the extruder with a dosing pump.

Figure 8.1: Schematic diagram of the twin-screw co-rotating extruder Cleextral BC21. (Li, 1998)



The screw configuration used in the experimental work was kept constant. The configuration used is shown in Figure 8.2 below. This configuration consists of forward screw elements gradually decreasing in pitch, mixing paddles and a pair of reverse elements. The die used in the experimental work was a 2mm circular die, the die was kept constant for all experimental runs.

Figure 8.2: Schematic diagram of the screw configuration used. (Li, 1998)



- A:** Forward Screw Element, 13mm pitch, 50mm length
- B:** Forward Screw Element, 10mm pitch, 50mm length
- C:** Forward Screw Element, 7mm pitch, 25mm length
- D:** Forward Screw Element, 7mm pitch, 25mm length
- RSE:** Reverse Screw Element, 7mm pitch, 25mm length
- KD:** Bi-lobal kneading disks, forward conveying

The rotational screw speed, barrel temperature, feed rate and water feed rate were controlled and the torque and die pressure were recorded. The visual display in the extrusion program (Li, 1998) on an Allen-Bradley data station was used to ensure that steady state had been reached before samples were taken.

8.2.3. Post-extrusion Treatment

The product was dried for 8 hours using a Whitlock Speedy Smoke'n'Cooker forced convection air oven (Progressive Machinery Design Ltd., Auckland) at a temperature of 100°C and air speed of 2ms⁻¹. The products were allowed to cool and then stored in sealed plastic bags. A sample from each bag was taken and ground for nutritional testing and then stored in sealed plastic containers to maintain moisture. The moisture content was measured and the results reported on a dry weight basis. The moisture content of the bulk samples was not adequately maintained during storage. Since texture is moisture dependent, the water activity of the samples was equilibrated prior to conducting texture analysis.

8.2.4. Sighter Trials

Two sighter trials, i.e., exploratory experiments, were conducted in order to establish boundaries for the dietary fibre and processing conditions required to produce an expanded oat product. More specifically, these trials were used to determine the suitability of various raw materials including oat flour, oat bran, naked oats, flaxseed fibre, maize starch and corn grits and gauge the limitations of the oat bran addition level, starch addition and starch type on product expansion.

The dietary fibre content for selected samples was determined in order to provide an indication of the effect of extrusion processing using the Clextral BC21 extruder. The effect of addition of citric acid (acid hydrolysis) on dietary fibre content was also determined, in order to establish whether resistant starch could be formed in this extruder. Selected formulations trialled in the sighter trials are presented in Table 8.2 below.

Table 8.2: Formulations used for Extrusion Sighter Trials

	<i>Formulation</i>	<i>Oat Flour (%)</i>	<i>Oat Bran (%)</i>	<i>Starch (%)</i>	<i>Citric Acid (%)</i>
Sighter trial 1	1	100			
	2	90	10		
	3	70	30		
Sighter trial 2	4	90		10 (Std)	
	5	82.5		10 (HA)	7.5
	6	80	10	10 (Std)	

Processing Conditions

Table 8.4 shows that the extruder settings were varied for the sighter runs because it was necessary to ensure that a suitable product eventuated. These trials were also used to determine appropriate extruder settings, including extruder barrel temperature, screw speed, water feed rate and ingredient feed rate.

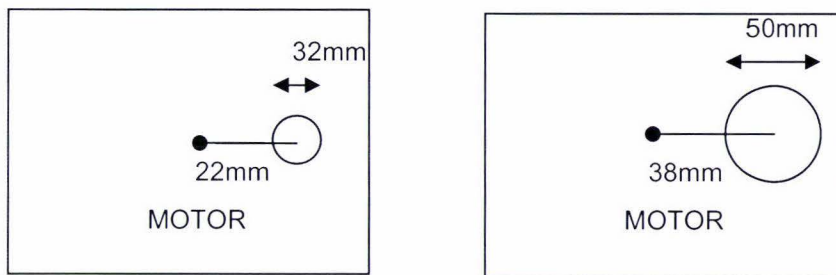
Table 8.3: Processing Conditions used for Extrusion Sighter Trials

<i>Formula</i>	<i>Screw Speed rpm</i>	<i>Feed Rate Rpm</i>	<i>Water Feed Lh⁻¹</i>	<i>Temp Barrel 1 °C</i>	<i>Temp Barrel 2 °C</i>	<i>Temp Barrel 3 °C</i>	<i>Temp Barrel 4 °C</i>
1	297	60	0.60	55	90	100	130
2	297	60	0.35	55	90	110	130
3	297	61	0.32	55	90	110	130
4	398	131	0.37	55	90	120	150
5	398	76	0.36	55	90	110	130
6	398	76	0.36	55	90	110	130

8.2.5. Hopper Modification

In the sighter trial an observation was made that the extruded samples were extremely variable due to an inconsistent feed rate caused by bridging of the powdered raw materials in the feeder.

A vibration unit was constructed and mounted onto the side of the hopper to address this problem. Schematic diagrams of the vibration units trialled are shown in Figure 8.3 below and the positioning of the vibration unit is outlined in Figure 8.4.

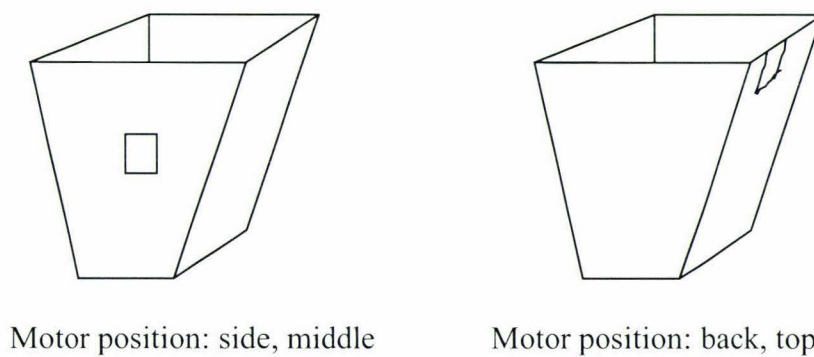
Figure 8.3: Schematic diagram of vibration units

Vibration unit 1

Vibration unit 2

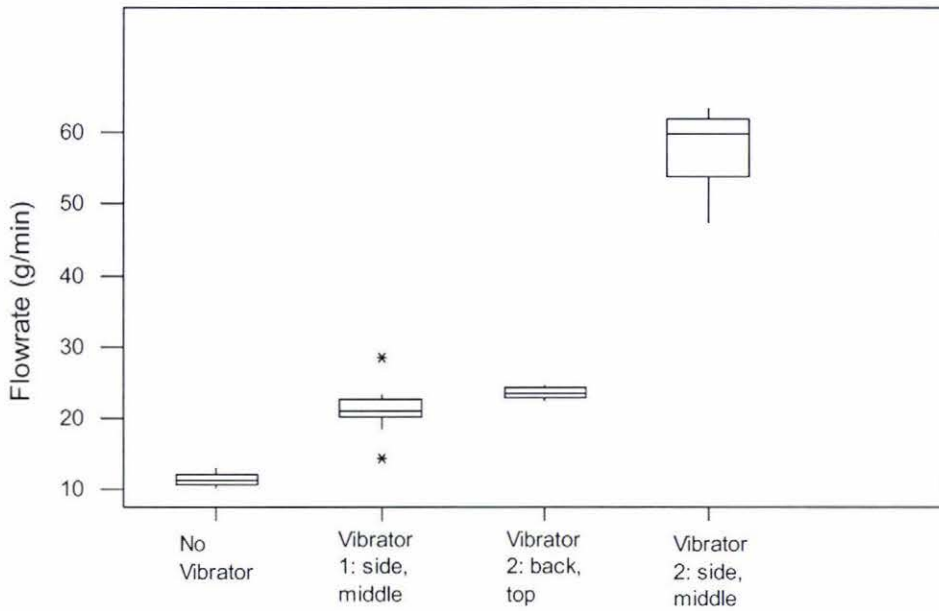
Note: Not drawn to scale.

Vibration unit 1 consisted of a motor with a 32mm weight attached and 22mm offset. Vibration unit 2 consisted of the same motor with a 50mm weight attached and 38mm offset.

Figure 8.4: Schematic diagram of the positioning of vibrator units on the extruder hopper

Motor position: side, middle

Motor position: back, top

Figure 8.5: Variation in Feed Flow rate with and without Vibration

Vibrator unit 1: Diameter of weight = 32mm, offset = 22mm

Vibrator unit 2: Diameter of weight = 50mm, offset = 38mm

The dry hopper screw feed speed was set at 58-60rpm. Figure 8.5 shows the effects that the vibrator and its positioning had on the feed rate to the extruder and the percentage variability in the feed rate. The figure shows that the nominal feed flow rates were higher with the vibration unit mounted onto the feed hopper. It is the percentage variation in feed rate that is of greatest interest, as the objective was to minimise feed rate variability, an issue that had been identified in sighter trials. Figure 8.5 illustrates that the feed rate increased from 11.37 g/min ($\pm 7.67\%$) without vibration to 23.54 g/min ($\pm 3.16\%$) with vibrator 1 attached at the top back and 21.28 g/min ($\pm 16.69\%$) when attached at the side, halfway down. The feed rate for vibrator 2 attached on the side, halfway down was 58.09g/min ($\pm 8.66\%$). Therefore, the vibration unit was mounted at the top, back to provide the most consistent feed flow rate for the factorial experiment.

8.2.6. Factorial Experiment

A 24 run (2x2x2x3) full factorial design was conducted to determine the effect of starch type (3), starch level (2), enzyme pre-treatment (2) and extruder setting combination (2) on dietary fibre content and solubility, β -glucan content, product expansion, hardness and appearance.

Table 8.4: Factorial Design

	<i>Starch Type</i>	<i>Starch Level (%)</i>	<i>Oat Bran (%)</i>	<i>Oat Flour (%)</i>	<i>Enzyme Pretreatment</i>	<i>Extruder Setting</i>
1	Waxy	20	20	60	+	Low
2	Waxy	20	20	60	+	High
3	Waxy	20	20	60	-	Low
4	Waxy	20	20	60	-	High
5	Waxy	40	20	40	+	Low
6	Waxy	40	20	40	+	High
7	Waxy	40	20	40	-	Low
8	Waxy	40	20	40	-	High
9	Std	20	20	60	+	Low
10	Std	20	20	60	+	High
11	Std	20	20	60	-	Low
12	Std	20	20	60	-	High
13	Std	40	20	40	+	Low
14	Std	40	20	40	+	High
15	Std	40	20	40	-	Low
16	Std	40	20	40	-	High
17	HA	20	20	60	+	Low
18	HA	20	20	60	+	High
19	HA	20	20	60	-	Low
20	HA	20	20	60	-	High
21	HA	40	20	40	+	Low
22	HA	40	20	40	+	High
23	HA	40	20	40	-	Low
24	HA	40	20	40	-	High

Note: The “low” extruder setting refers to the lower screw speed set of conditions:

Extruder screw speed: 250rpm, Water feed rate: 0.24 Lh⁻¹

The “high” extruder settings refers to the higher screw speed conditions:

Extruder screw speed: 300rpm, Water feed rate: 0.108 Lh⁻¹

All other extruder conditions were held constant at the following settings:

Raw material feed rate: 46 kgh⁻¹

Barrel temperature profile: 60°C, 90°C, 110°C, 130°C for barrels 1 to 4 respectively.

8.2.6.1. Starch Pre-Treatment

Promozyme[®] 400L was added to a 25% starch slurry at a concentration of 10g/kg (Eiman, Personal Communication, 2002) to hydrolyse the 1,6-alpha linkages in the amylopectin in order to promote resistant starch formation within the extruder. The pH of the starch slurry was adjusted to pH 5.0 using NaOH or HCl and the slurry was heated to 60°C for 30 minutes (refer to specification shown in **Appendix D-6**). This treatment provided optimal enzyme activity. The enzyme was not inactivated as complete starch hydrolysis was desired and the enzyme would be inactivated in the extrusion process. The starch slurries were dried in an air oven at 50°C for 16 hours. The starch needed to be dried so that it could be blended with oat flour and bran and used to feed the extruder. Starch was ground into a coarse powder using a Beco pilot scale grinder press and then ground to a finer particle size using a Breville Coffee and Spice Grinder (Model CG2, Breville Pty Ltd., China) for 30 seconds. For runs where no enzyme was added the same process was conducted, but no enzyme added. The particle size distribution of the pre-treated starches is outlined in Table 8.5 below.

Table 8.5: Particle Size Distribution of Treated Starch

<i>Starch Type</i>	<i>Enzyme</i>	<i>>850μm %</i>	<i>500-850μm %</i>	<i>300-500μm %</i>	<i><300μm %</i>
Waxy	+	45.92	24.51	14.67	14.90
Waxy	-	36.87	29.73	18.02	15.37
Standard	+	38.80	26.33	17.60	17.28
Standard	-	15.65	31.00	23.79	29.55
HA	+	35.14 \pm 4.32	19.26 \pm 0.57	42.89 \pm 1.68	2.71 \pm 0.35
HA	-	28.40 \pm 14.40	27.16 \pm 2.49	22.55 \pm 1.52	21.89 \pm 3.44

8.3 Nutritional Analysis

8.3.1. Dietary Fibre

Soluble and insoluble dietary fibre was tested using a Megazyme Total Dietary Fibre kit (Megazyme, Ireland). The method used was a simplified method utilised by Megazyme based on the American Association of Analytical Chemists (AOAC) 991.43 method “Total, Soluble and Insoluble Dietary Fiber in Foods” and American Association of Cereal Chemists (AACC) Method 32-07 “Determination of Soluble, Insoluble and Total Dietary Fibre in Foods and Food Products” (Megazyme, 2001).

Dried food samples were sequentially digested with heat stable α -amylase, protease and amyloglucosidase. The samples were cooked at 95 – 100°C with heat stable α -amylase for 35 minutes. This resulted in the gelatinisation, hydrolysis and depolymerisation of starch. The sample was then incubated for 30 minutes at 60°C with protease to solubilise and depolymerise the proteins whilst the amyloglucosidase hydrolysed the starch fragments to glucose.

The digested samples were filtered and the insoluble dietary fibre residue rinsed with warm de-ionised water and dried overnight. The combined filtrate and water washings were precipitated with (4 volumes) 95% ethanol (ethanol was added to precipitate soluble fibre and remove the depolymerised protein and glucose from the starch); the soluble fibre was filtered and dried. The protein and ash content of the dried residues were determined and corrected for in the determination of insoluble and soluble dietary fibre, along with the reagent blank.

Nitrogen

Nitrogen analysis was conducted using a Leco FP-2000 Protein/Nitrogen analyser (Leco Corporation, USA) according to the method of Dumas (1831). Conversion factor used was 6.25. Testing was contracted to the Massey University Nutrition Laboratory.

Ash

Crucibles containing the dried fibre residues were ashed at 525°C for 5 hours according to the method stated by Megazyme. The ash content was determined from the difference in weight before and after ashing.

Dietary Fibre Estimation

The dietary fibre calculations are described by equations 1 and 2 below.

$$\text{Dietary Fibre(\%)} = \frac{\left(\left(R_1 + \frac{R_2}{2} \right) - p - A - B \right)}{m_1 + \frac{m_2}{2}} \times 100 \quad \text{(Equation 1)}$$

R_1 = residue weight 1 from m_1 ; R_2 = residue weight 2 from m_2 ;

m_1 = sample weight 1; m_2 = sample weight 2;

A = ash weight from R_1 ;

p = protein weight from R_2 ; and

$$B = \text{blank} = \frac{B_{R1} + B_{R2}}{2} - B_P - B_A \quad (\text{Equation 2})$$

where: B_R = blank residue; B_P = blank protein from B_{R1} ; B_A = blank ash from B_{R2} .

The Total dietary fibre content was determined by addition of the IDF and SDF values.

Fibre contents were adjusted for moisture and reported on a dry weight basis using equations 3-5.

$$\% \text{ dry matter (DM)} = 100 - \text{TM} \quad (\text{Equation 3})$$

$$\text{DF (dwb)} = \frac{\text{DF(wwb)}}{\text{DM}} \quad (\text{Equation 4})$$

Where:

DF(dwb) = dietary fibre content on a dry weight basis.

Note TDF(dwb) denotes Total dietary fibre on a dry weight basis etc.

DM = % dry matter

TM = % Total Moisture

Dietary Fibre Contents of Raw material blends were calculated by:

DF (dwb) blend =

$$\frac{(x_1 \times DM_1 \times DF(dwb)_1) + (x_2 \times DM_2 \times DF(dwb)_2) + \dots + (x_n \times DM_n \times DF(dwb)_n)}{(x_1 \times DM_1 + x_2 \times DM_2 + \dots + x_n \times DM_n)}$$

(Equation 5)

Where:

X = % of component in blend

and subscripts A, B, ...x denote raw material component A, B, ...x.

8.3.2. Beta-Glucan

Beta-glucan content was determined using an assay kit supplied by Megazyme International (Ireland). The method used was the "Assay of Mixed Linkage beta-glucan in oat and barley flour and fibre samples – streamlined method" (Megazyme, 1998).

Samples were reacted with purified lichenase enzyme (10U) after suspension and hydration in a sodium phosphate buffer solution at pH 6.5 to break the 3,4 β -glucan linkages to form β -gluco-oligosaccharides (Megazyme, 1998). Samples were incubated at 40°C for one hour.

An aliquot of the filtrate was reacted to completion (to form glucose) with purified β -glucosidase enzyme (0.2U) in 50mM acetate buffer (pH 4.0) at 40°C for 15 minutes. The glucose produced was assayed using glucose oxidase/oxidase (GOPOD) reagent and the absorbance at 510nm was measured. Calculations took into account the conversion from free glucose to anhydro-glucose as occurs in β -glucan.

Extruded cereal samples were pre-extracted using 50% aqueous ethanol to remove free sugars and to reduce the level of fats and oils.

Beta-glucan calculations are described by equations 6 and 7 below.

$$\% \beta - glucan = \Delta E \times F \times 94 \text{ (or 64 for extruded)} \times \frac{1}{1000} \times \frac{100}{W} \times \frac{162}{180} \quad \text{(Equation 6)}$$

$$= \Delta E \times \frac{F}{W} \times 8.46 \text{ (or 5.71 for extruded products)} \quad \text{Equation 7}$$

Where:

DE = Absorbance after β -glucosidase treatment minus blank absorbance.

F = a factor for the conversion of absorbance values to μ grams of glucose.

$$= \frac{100 \text{ (micrograms of glucose)}}{\text{GOPOD absorbance for 100 micrograms of glucose}}$$

94 = volume correction factor (0.1 mL out of 9.4 mL was analysed for cereal samples).

64 = volume correction factor (0.1 mL out of 6.4 mL was analysed for cooked, toasted and extruded cereal products).

1/1000 = conversion from micrograms to milligrams.

100/W = conversion back to 100 mg of sample.

W = weight of sample analysed.

162/182 = a factor to convert from free glucose, as determined, to anhydro glucose, as occurs in β -glucan.

Beta-glucan contents were adjusted for moisture and reported on a dry weight basis according to formula 8 below.

β -Glucan Content of Raw Blend (dry weight basis)=

$$= \frac{(\% \text{ oat flour} \times \% \text{ dry solids} \times \beta - \text{Glucan}(\text{oat flour})) + (\% \text{ oat bran} \times \% \text{ dry solids}(\text{oat bran}) \times \% \beta - \text{Glucan}(\text{oat bran}))}{\% \text{ Dry Solids (Total)}}$$

Accuracy

The accuracy stated in the Megazyme test method is $4.0\% \pm 0.1\%$ for a standard barley sample. Since the test kit and test method covered the measurement of both oat β -glucan and barley β -glucan, it was assumed that the accuracy was the same for oat.

8.3.3. Moisture

Moisture was determined by the air-convection method described in Winger *et al.* (1999) subject to the time temperature conditions of 105°C for 12 hours.

8.4 Physical Properties

8.4.1. Diameter

Sixteen extrudate samples (cut to approximately 10mm) were randomly selected from each run. The diameter was measured in the centre of each sample using a pair of Vernier callipers (Mitutoyo, Japan) and the average calculated.

8.4.2. Texture Analysis

Dried extrudate samples were cut to 10mm cylinders. The moisture content of all samples was equilibrated to a water activity of 0.185. Samples were equilibrated by placing extrudates over a saturated sodium hydroxide solution at 40°C for 7 days in a sealed container.

Texture analysis was conducted using the Instron 1140 Texture Analyser (500N loadcell) (Instron Corp., USA). The Instron was interfaced to a Powerlab 4SP data conversion unit (AD Instruments, Australia). Data was collected using the Chart 4 data collection software package. The textural parameter measured was hardness. A puncture test was conducted to measure the force to puncture through 50% of the sample. A 4mm diameter cylindrical probe and crosshead speed of 100mm/minute was used. Six

measurements were taken for each sample, and two of the 24 samples were randomly selected and repeated.

8.5 Statistical Analysis

Statistical analysis was conducted on the data collected from the factorial experiment only. Statistical analysis was conducted using the Minitab Statistical Package version 13 (Minitab Inc, USA). Multi-vari charts were plotted to illustrate data and analysis of variance (General Linear Model) was conducted to determine significant relationships at the 95% confidence level.

8.6 Results

8.6.1. Sighter Trial

Sighter trials were conducted to gain information about the selection of raw materials and acceptable extruder process conditions.

8.6.1.1. Selection of raw materials

The two sighter trials indicated that a number of raw materials would need to be excluded from further experimentation as they were either impractical or produced unacceptable products. The excluded raw materials and the reasons for their exclusion are provided below:

Naked Oats: the use of naked oats on their own resulted in unacceptable products with low expansion. It was impractical to blend naked oats (large particulates) with starch to increase expansion and hence oat flour and oat bran was used in preference.

Corn grits: the large corn grit particulates were not able to be homogeneously mixed throughout the powder feed, and were therefore replaced with starch in the factorial experiment.

Flaxseed fibre: the addition of flaxseed fibre resulted in visually unacceptable (very dark, non-expanded) and very hard products

8.6.1.2. Selection of process conditions

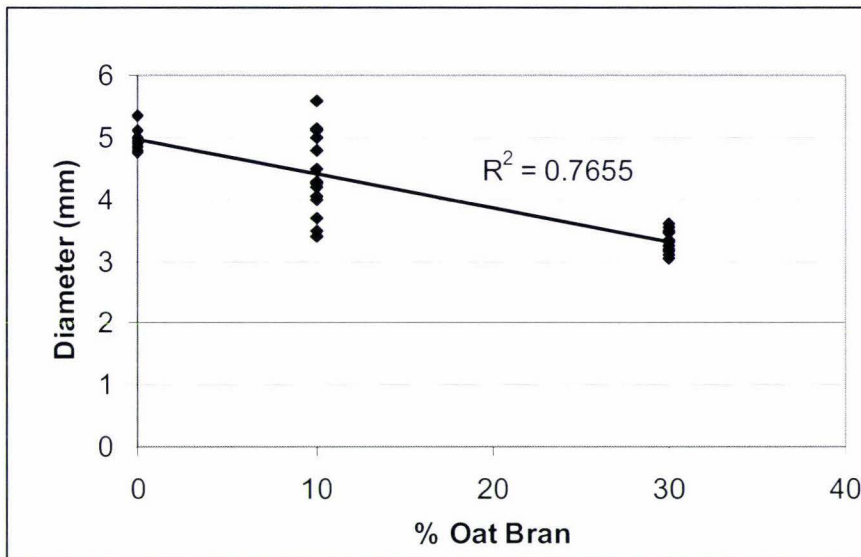
Temperature

The temperatures in the 2nd, 3rd and 4th barrels are known to be of critical importance in the extrusion process. In the extruder used for the study barrel 1 (see Fig. 8.1) does not have an independent heating unit and is heated by conduction only. The temperature in barrel 4 is generally set and the temperature of barrels 2 and 3 are then set so as to achieve a gradual temperature increase along the length of the extruder barrel. From the initial sighter trials it was determined that a barrel temperature profile of ~60°C 90°C 110°C 130°C, for barrels 1 to 4 respectively, was suitable to obtain a cooked and expanded product, where cooked products were defined as those extrudates that were edible and had expanded to a diameter larger than the die. Samples extruded at lower temperatures (120°C) were not suitably cooked and products extruded at higher temperatures (150°C) were burnt. Therefore, a temperature of 130°C was used in the subsequent factorial experimental design.

8.6.1.3. Expansion

The effect of oat bran addition on expansion was determined by comparing the diameter of samples containing 0% oat bran (Formulation 1), 10% oat bran (Formulation 2) and 30% oat bran (Formulation 3). It is important to note however that the water feed rate used in processing formulation 1 was higher than formulation 2 and 3. A higher water feed rate was required in this instance to obtain a suitable product and prevent blockage of the extruder. Despite this confounding, a comparison between formulation 2 and 3 (processed under the same conditions) showed a decreasing expansion trend with oat bran addition and further comparison with formulation 1 supports this trend. These results are shown in Figure 8.6 below.

Addition of oat bran caused a significant reduction in expansion at both the 10% ($p=0.002$) and 30% ($p=0.000$) addition level. The diameter was reduced from a mean diameter of 5.00 (± 0.04)mm with no oat bran to 4.37 (± 0.16)mm with 10% oat bran and 3.34 (± 0.046)mm with 30% oat bran.

Figure 8.6: Effect of Oat Bran addition on Expansion

The effect of starch addition on expansion could not be obtained in this trial because neither varying the starch type nor percentage composition of starch produced a continuous flow of cooked extrudate samples. Consequently, these two variables were included in the final factorial experiment.

Due to the difference in extruder processing conditions, the combined effect of oat bran and starch addition was gauged informally through a comparison of formulation 6 (10% starch + 10% oat bran) with formulation 2 (10% oat bran) and formulation 4 (10% starch). Addition of 10% starch and 10% oat bran (formulation 6) resulted in samples with a larger mean diameter than samples with 10% oat bran and no starch (formulation 2) ($p=0.000$). Moreover, the expansion in formulation 2 appeared to be greater than samples with 10% starch and no oat bran (formulation 4). Since oat bran was shown to decrease expansion (as shown by Figure 8.6 above), it was expected that samples with oat bran and starch would be less expanded than samples with only starch.

8.6.1.4. Dietary Fibre

Comparison of fibre contents of the raw ingredients with the extruded samples indicated that soluble fibre was increased during the extrusion process and that insoluble fibre decreased, as shown in Table 8.6 below. The total dietary fibre level appeared to also have increased slightly, an indication that resistant starch may have been forming in the extrusion process. Addition of oat bran (Formulation 3) increased both the soluble and

total dietary fibre content compared to samples with 100% oat flour (Formulation 1). The analytical method for dietary fibre determination and details of calculations are outlined in section 8.3.1. Duplicate measurements were unable to be completed for all formulations due to the time and financial constraints of dietary fibre testing.

Table 8.6: Effect of Extrusion and Oat bran addition on dietary fibre content (dry weight basis)

<i>Material</i>	<i>Treatment</i>	<i>IDF (%)</i>	<i>SDF (%)</i>	<i>TDF (%)</i>
Oat Flour (Formulation 1)	Raw	5.86±0.05	1.25±0.10	7.10±0.14
	Extruded	4.72	2.22	6.94
Oat Flour + 30% Oat Bran (Formulation 3)	Raw	6.72	1.71	8.43
	Extruded	6.26	2.88	9.14

8.6.1.5. Effect of citric acid addition

Table 8.7: Effect of citric acid addition on dietary fibre content and composition (dry weight basis)

<i>Material</i>	<i>Treatment</i>	<i>IDF (%)</i>	<i>SDF (%)</i>	<i>TDF (%)</i>
Oat Flour + 10% Starch + 7.5% Citric Acid (Formulation 8)	Raw	5.80	1.23	7.04
	Extruded	4.36	2.38	6.74

Table 8.7 shows that addition of citric acid appeared to increase soluble dietary fibre (SDF) at the expense of insoluble dietary fibre (IDF), but total dietary fibre (TDF) decreased which indicates that resistant starch had not been formed as a consequence of citric acid addition. In the factorial experiment, enzyme hydrolysis was investigated to determine the effect on resistant starch formation.

8.6.2. Factorial Design Experiment

A full factorial experiment was conducted in order to determine the effects of the controlled variables on various responses. The controlled variables were starch type, starch percentage, enzyme treatment and process settings. The response variables considered were torque, pressure at the die (P_{die}), expansion, hardness, insoluble, soluble and total dietary fibre (IDF, SDF, TDF respectively) and β -glucan. Torque is the rotational force created by the turning extruder screws and the die pressure is the pressure created by the product behind the die. The methods of measurement of expansion, hardness, IDF, SDF, TDF and β -glucan are outlined in section 8.2. The extruder response results and product physical properties are summarised in Table 8.8. The nutritional analyses are summarised in Table 8.9, in section 8.6.2.3. The

experimental treatments for each run (formulation, process settings and enzyme treatment) are shown in Table 8.4, section 8.2.

Unfortunately it was not possible to develop a model for the various response variables as an incomplete data set was collected due to time and financial constraints. Consequently the factors were analysed separately.

Table 8.8: Summary of Extruder response variables and Physical Properties for Factorial Experiment

<i>Run</i>	<i>Torque (Nm)</i>	<i>P_{die} (bar)</i>	<i>Diameter (mm)</i>	<i>Hardness (N)</i>
1	3.3	62	5.59 ± 0.28	0.0023 ± 0.0006
2	3.4	65	5.59 ± 0.53	0.0020 ± 0.0004
3	6	83	4.67 ± 0.54	0.0014 ± 0.0001
4	5.9	80	4.46 ± 0.75	0.0017 ± 0.0003
5	8.1	122	8.17 ± 0.47	0.0007 ± 0.0001
6	8.8	133	9.19 ± 0.64	*
7	8.4	78	8.69 ± 0.63	0.0005 ± 0.0001
8	6.9	64	7.24 ± 0.64	0.0006 ± 0.0001
9	*	*	3.11 ± 0.26	0.0033 ± 0.0011
10	7	105	3.95 ± 0.56	0.0020 ± 0.0006
11	6.35	105	2.98 ± 0.24	0.0033 ± 0.0014
12	5.95	97	4.49 ± 0.64	0.0014 ± 0.0005
13	8.2	116	7.09 ± 0.34	0.0008 ± 0.0001
14	6.85	93	6.37 ± 0.43	0.0009 ± 0.0001
15	8.25	143	7.61 ± 0.49	0.0010 ± 0.0001
16	7	136	6.95 ± 0.31	0.0010 ± 0.0002
17	6.5	57	2.78 ± 0.45	0.0013 ± 0.0004
18	6	54	2.79 ± 0.31	0.0010 ± 0.0001
19	7.3	114	*	*
20	7.3	136	5.51 ± 0.50	0.0014 ± 0.0003
21	7.7	93	6.20 ± 0.43	0.0010 ± 0.0002
22	6.7	81	6.01 ± 0.53	0.0009 ± 0.0001
23	7.3	84	6.09 ± 0.60	0.0009 ± 0.0001
24	6.7	78	5.43 ± 0.92	0.0009 ± 0.0002

*denotes a missing value.

8.6.2.1. Extruder Output Variables

Torque is an extruder response variable which indicates the amount of work that is applied to the dough and is related to screw speed, degree of fill in the barrel and the viscosity of the dough. The torque and pressure at the die (P_{die}) for each of the experimental runs are outlined in Table 8.8 above.

Torque

Analysis of variance of the torque results (Table 1, **Appendix E-2**) shows that starch level in the formulation had a significant effect on the motor torque ($p=0.002$), higher starch levels resulted in higher torque values. Increasing the starch level from 20% to 40% caused a mean increase in torque of $5.00(\pm 1.08)\text{Nm}$, from $17.73 (\pm 1.24)\text{Nm}$ for the 20% starch samples to $22.73 (\pm 0.65)\text{Nm}$ for the 40% starch samples (Table 1, **Appendix E-2**). This difference was larger for the waxy starch samples, as illustrated in Figures 8.7 and 8.8 below. There was also a significant interaction between starch type and level ($p=0.018$).

There was no difference in the torque values and hence the amount of work as a result of using different starch types, enzyme treatment or extruder process settings, i.e., the amount of work applied to the dough was similar for each of the three treatment effects, as shown by Figure 8.7 below.

Figure 8.7: Effect of Factors on Torque

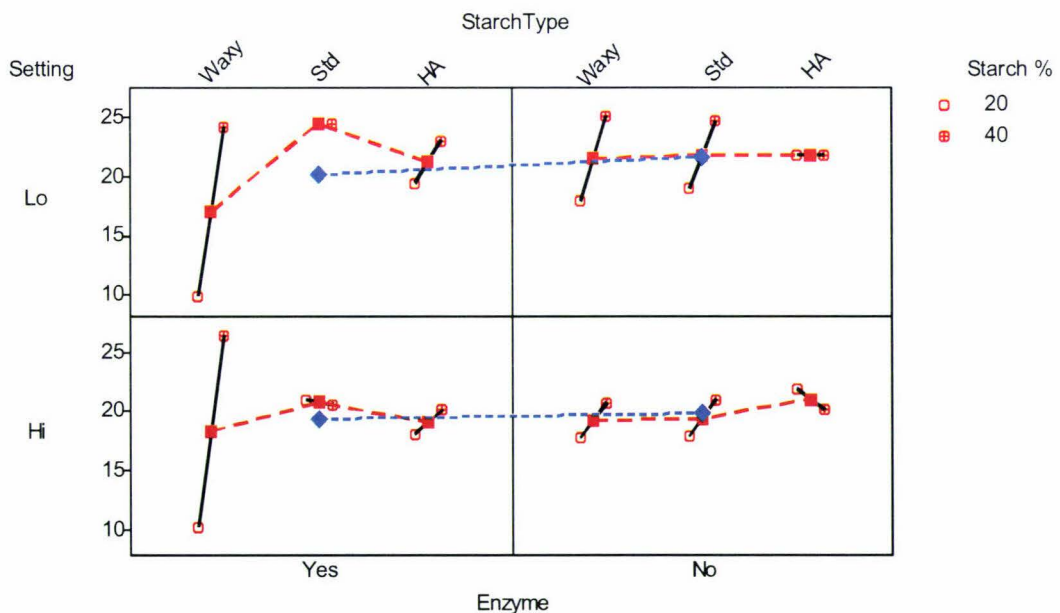
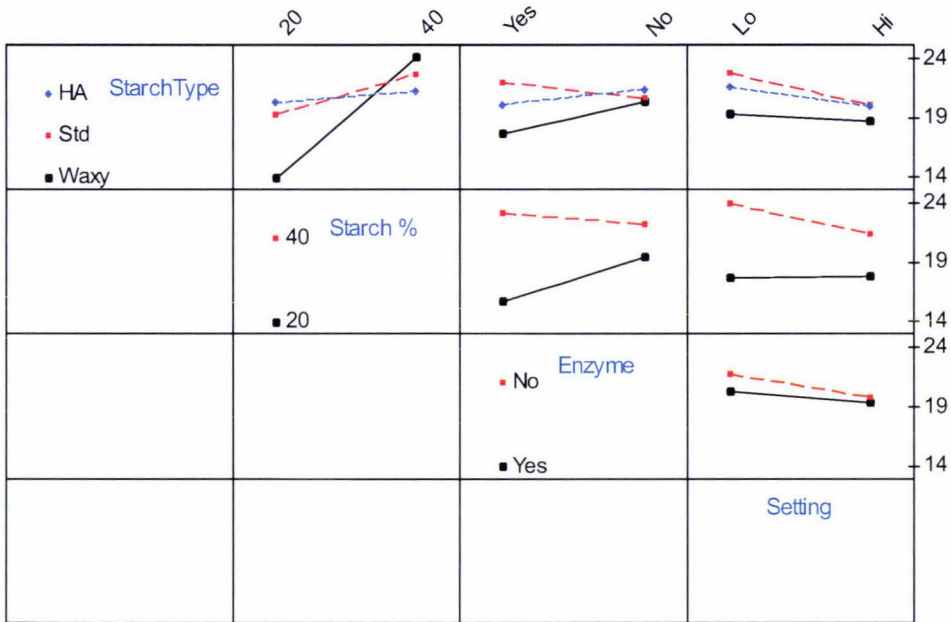


Figure 8.8: Interaction Plot for Effect of Factors on Torque



Since the screw speed and water feed rate were altered simultaneously, these two factors were confounded. Therefore several additional data points were collected to provide a ‘one variable at a time’ comparison to give an indication of whether one of these process variables had an effect on torque. Water feed rate was found to have the greatest effect. The torque increased as the water feed rate was decreased (Figure 8.10), however there was negligible difference in the resultant torque (Figure 8.9) between using a screw speed of 250rpm and 300rpm.

Figure 8.9: Effect of Screw Speed on Torque

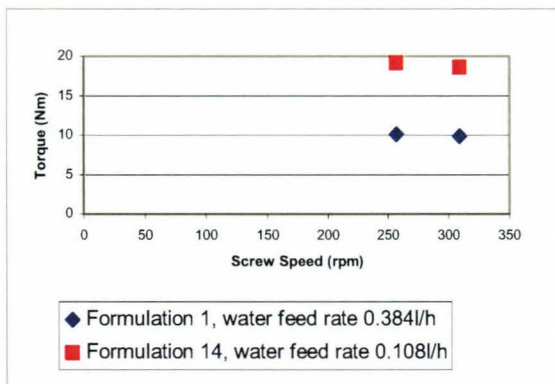
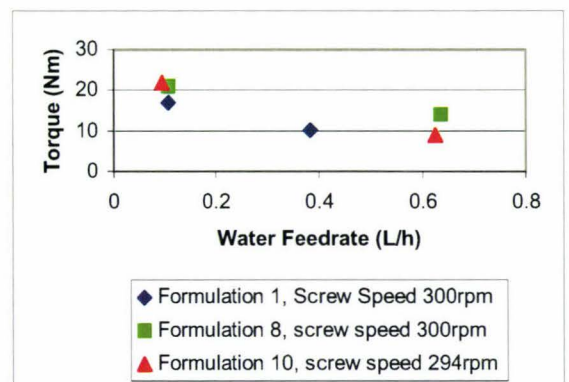


Figure 8.10: Effect of Water Feed Rate on Torque



Die Pressure

Analysis of variance of the die pressure results shows that only the starch level – enzyme interaction variable was significant at the 10% significance level ($p=0.052$) (shown in Table 2, **Appendix E-2**). The interaction plot shown in Figure 8.12 below shows that the pressure at the die was lower for samples with 20% starch treated with enzyme compared to the 40% starch, enzyme treated samples.

Figure 8.11: Effect of Factors on Die Pressure (Pdie)

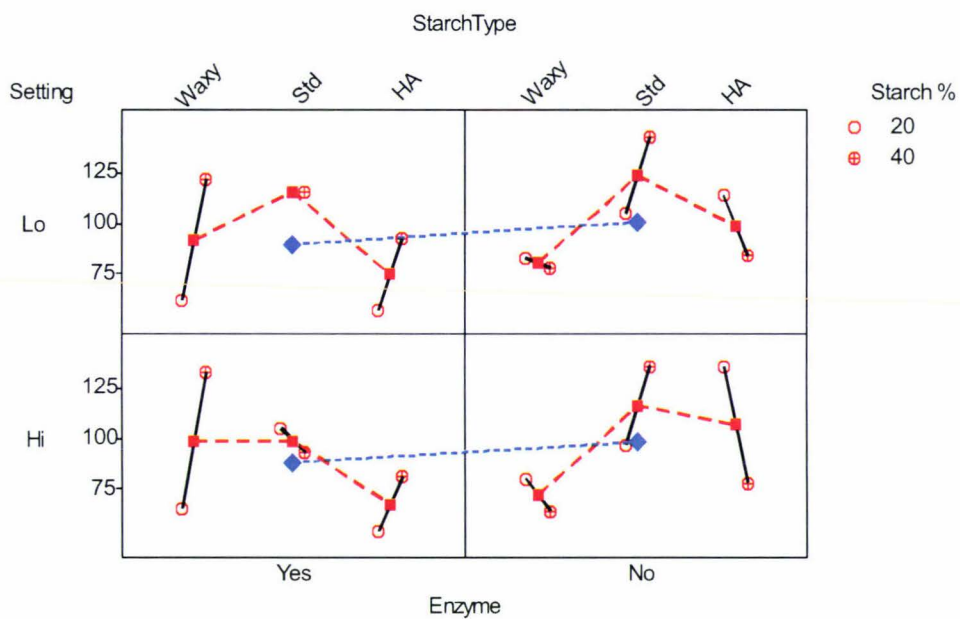
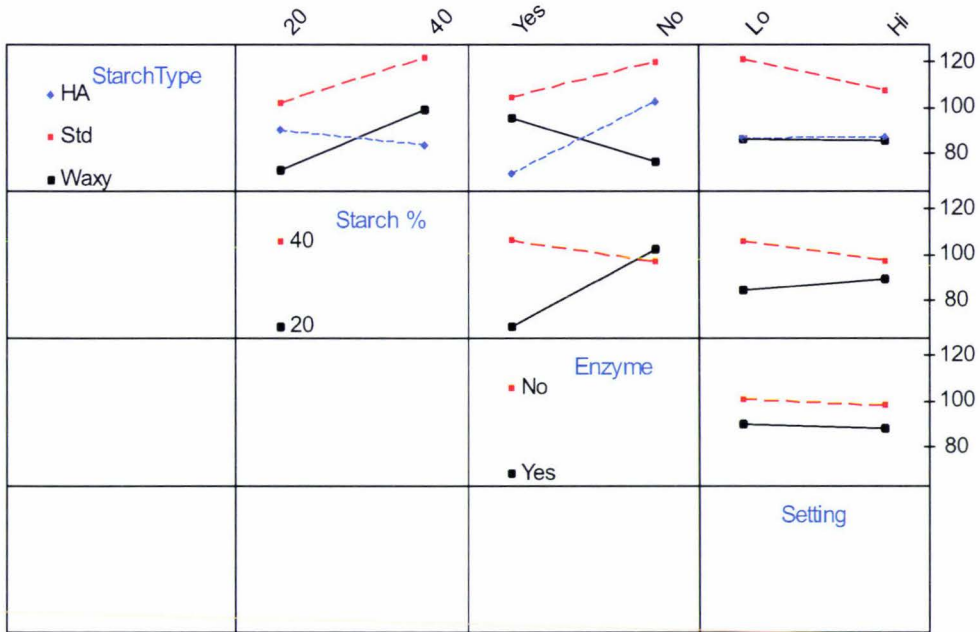


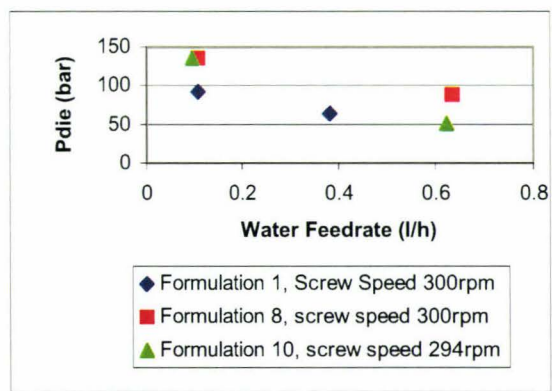
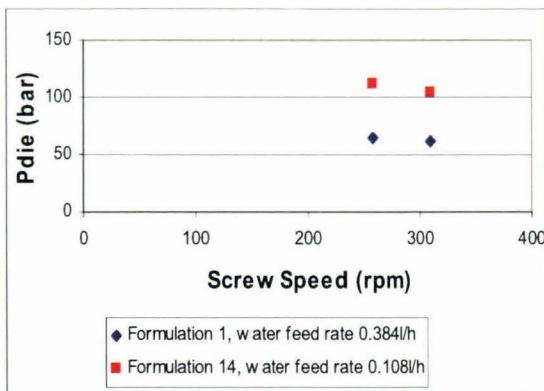
Figure 8.12: Interaction Plot for Die Pressure (Pdie)



The individual variable effect of water feed rate and screw speed on die pressure was shown by a ‘one variable at a time comparison’ using extra data points collected, in the same way as shown above for torque. The pressure at the die decreased with increased water feed rate (Figure 8.14) and had negligible change for screw speed (Figure 8.13).

Figure 8.13: Effect of Screw Speed on Pdie

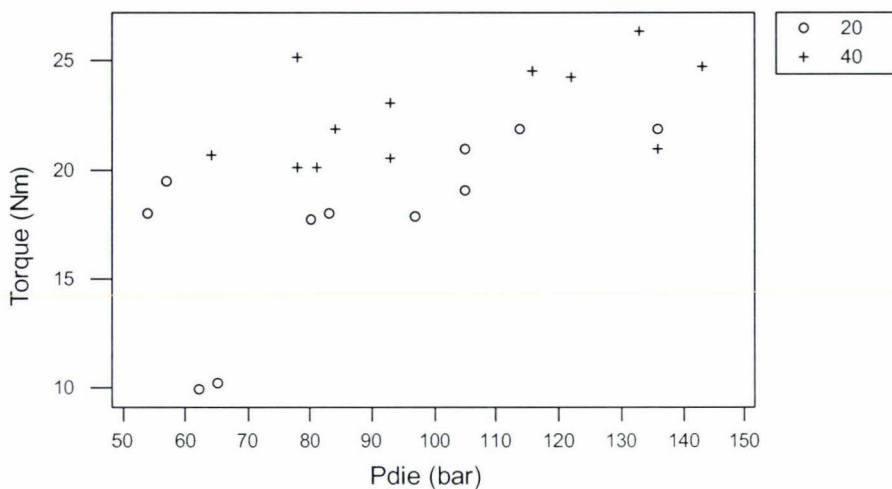
Figure 8.14: Effect of Water Feed Rate on Pdie



Torque and Die Pressure

Figure 8.15 shows that there was a linear relationship between torque and die pressure with die pressure increasing with increasing torque. This indicates that a greater amount of work applied to the dough as seen by a higher torque reading creates a greater amount of pressure behind the die.

Figure 8.15: Relationship between Torque and Die Pressure



Discussion

This study showed that as the level of starch in the formulations was increased it resulted in an increased torque. Several authors have shown that there is a relationship between soluble starch concentration and energy input, with increasing starch concentration leading to increased melt viscosity and hence higher screw torques (Meuser *et al.*, 1984, Guy and Horne, 1988, Ollett *et al.*, 1990 cited in Mitchell and Areas, 1992).

Although the confounded process settings used in the current factorial experiment had no effect on the torque or die pressure, informal investigation into the effect of individual variables, suggested that increased water feed rate decreased torque and die pressure. Van Lengerich, (1990, cited in Li, 1998) also showed that screw torque decreased with increased moisture content. Water acts as a plasticiser and melt viscosity is decreased with increased water content (Cervone and Harper, 1978, Senouci and Smith, 1988a, Altomare *et al.*, 1992, Lai and Kokini, 1990, Padmanabhan and

Bhattacharya, 1989, 1993a, 1993b, Vergnes *et al.*, 1993 cited in Li, 1998; Slade and Levin, 1988 cited in Kokini *et al.*, 1992). The decrease in viscosity was the reason for the decreased torque.

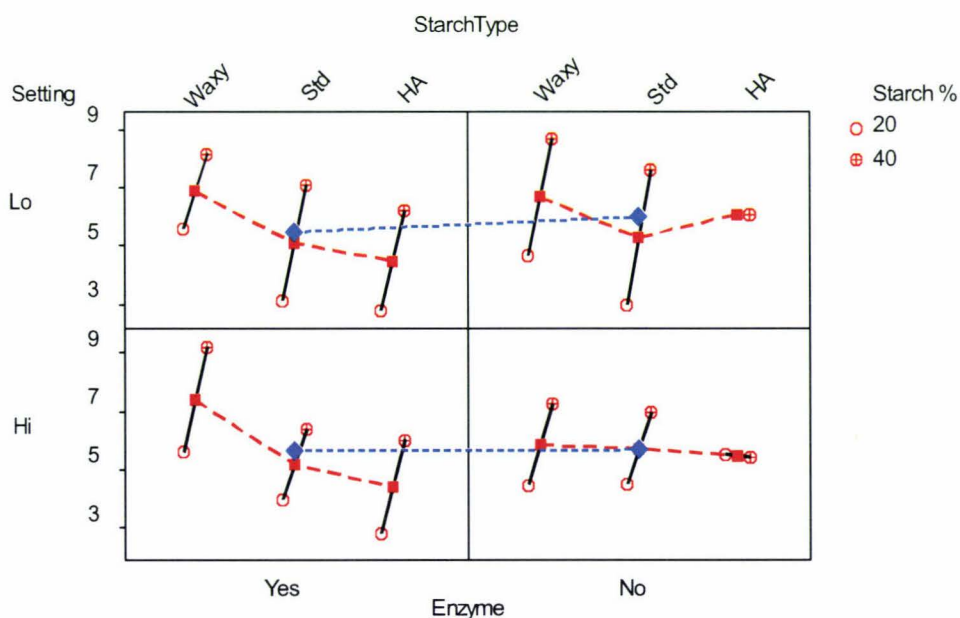
An increase in screw speed has been reported to lower the degree of fill in the extruder barrel (Li, 1998), a lower degree of fill results in higher specific mechanical energy (van Lengerich, 1990, cited in Li, 1998), a variable proportionately related to torque. In this research, the informal investigation indicated that the screw speed did not appear to have a significant effect on torque or die pressure, possibly due to the small difference in the screw speed settings used (250rpm and 300rpm).

8.6.2.2. Physical Properties

Expansion

The research results suggested that starch level had the largest effect on the expansion of extrudates. Increasing the level of starch from 20% to 40% resulted in an increase in the diameter of the extrudates of $2.92 (\pm 0.35)$ mm ($p=0.000$) (ANOVA table shown in Table 3, **Appendix E-2**). It appears that the increases were slightly more pronounced at lower screw speeds (Figure 8.16), however this effect was not significant at the 5% confidence level.

Figure 8.16: Effect of Factors on Expansion



The type of starch used had the second largest effect on the expansion of extrudates ($p=0.007$). Further examination using Tukey Comparison Tests showed that waxy starch resulted in higher expansion than standard or high amylose starch. The expansion of waxy starch was $1.38 (\pm 0.41)$ mm greater than standard starch ($p=0.023$) and $1.85 (\pm 0.44)$ mm greater than high amylose starch ($p=0.008$). There was no significant difference in the expansion of standard and high amylose starches ($p=0.565$). One exception worth noting was the 20% high amylose starch formulation (without enzyme treatment) processed at the high screw speed (300 rpm) combination which appeared to be more expanded than both the standard and waxy starch (shown in Figure 8.16 above). However this result was not significant at the 5% level.

Extrusion settings had no significant effect on expansion ($p=0.821$). However, there was some evidence that there was less product variation at low screw speeds (250 rpm) and high water content ($p=0.099$). Enzyme treatment had no significant effect on expansion ($p=0.771$). An Analysis of Variance Table for the response 'expansion' is shown in Table 3, **Appendix E-2**.

Discussion

The current research showed that extrudate expansion was increased by increasing the level of starch from 20% to 40%. Liu *et al.* (2000) found that the addition of 15% corn flour significantly increased the expansion ratio for an oat-corn puff compared to oat flour, but found no further significant increase with 30% corn flour addition. Increased starch levels resulted in a higher melt viscosity, which meant that fewer air bubbles collapsed at the exit of the die and hence expansion was retained.

Waxy starch (70% amylopectin) produced a more expanded product than standard or high amylose samples in the current experiment. This was in agreement with the observation of Feldberg and Smith (cited in Harper, 1981) and (Kokini *et al.*, 1992) who found that starches high in amylopectin produce more highly expanded extrudates, and Harper and Tribelhorn (1992), who showed the same effect in native cornmeals. A possible explanation for the greater expansion from the high amylopectin starches compared to the high amylose starches is related to the viscosity of the starches. The general principle is that expansion is dependent on bubble growth and bubble collapse. Kokini *et al.* (1992) found high amylose starches to have a higher viscosity. High

viscosity increases the pressure at the die can limit the vaporisation of superheated water resulting in less expansion (less bubble growth). High viscosity may also reduce bubble collapse (Kokini *et al.*, 1992). But the result of the highest expansion associated with high amylopectin starch is consistent with less bubble growth.

This research showed that simultaneously increasing the screw speed and decreasing the water feed rate had no effect on expansion, which was surprising since these settings when executed independently were expected to increase expansion. Moisture content has been shown to be one of the most important determinants of the expansion ratio (Mercier and Feillet, 1975, cited in Kokini *et al.*, 1992). Moisture content affects the viscosity of the melt, thermal energy and shear stress (Kokini *et al.*, 1992) which characterise expansion properties.

Increasing the screw speed causes a decrease in the residence time and an increase in pressure which in turn is expected to increase expansion according to Hseish & others (1990, cited in Murray, 2001). Screw speed has also been shown to increase expansion in wheat starch. It has been suggested that the effect may be due to the entrapment of a greater number of air bubbles due to the greater shear created by higher screw speeds when compared with low screw speeds (Hoseney *et al.*, 1992). In contrast, Harper (1981) suggests that screw speed has a minor effect on extrusion properties. The lack of effect of process settings (water feed rate and screw speed) on expansion in this research indicates that the change in extruder settings was not significant enough to have an impact on the product attributes.

Hardness

The study showed that starch level had the greatest effect on the hardness of the extruded samples ($p=0.001$) as illustrated in Figures 8.17 and 8.18. Increasing the starch level from 20% to 40% resulted in a decrease in the force required to puncture the sample of $0.0011 (\pm 0.00022)$ N ($p=0.0002$). However, it should be noted that there was a weak interaction between the starch level and extruder setting ($p=0.071$) and the starch level and starch type ($p=0.084$).

Figure 8.18 indicates that the difference in hardness between the two levels of starch was greater at the low screw speed (high water) extruder setting, and less pronounced for the high amylose starch.

Figure 8.17: Effect of Factors on Hardness

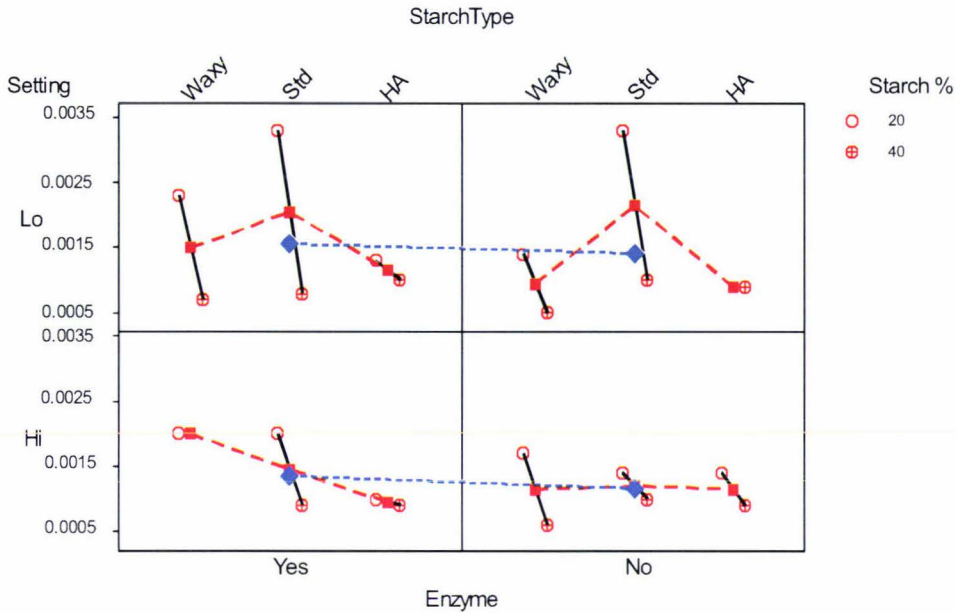
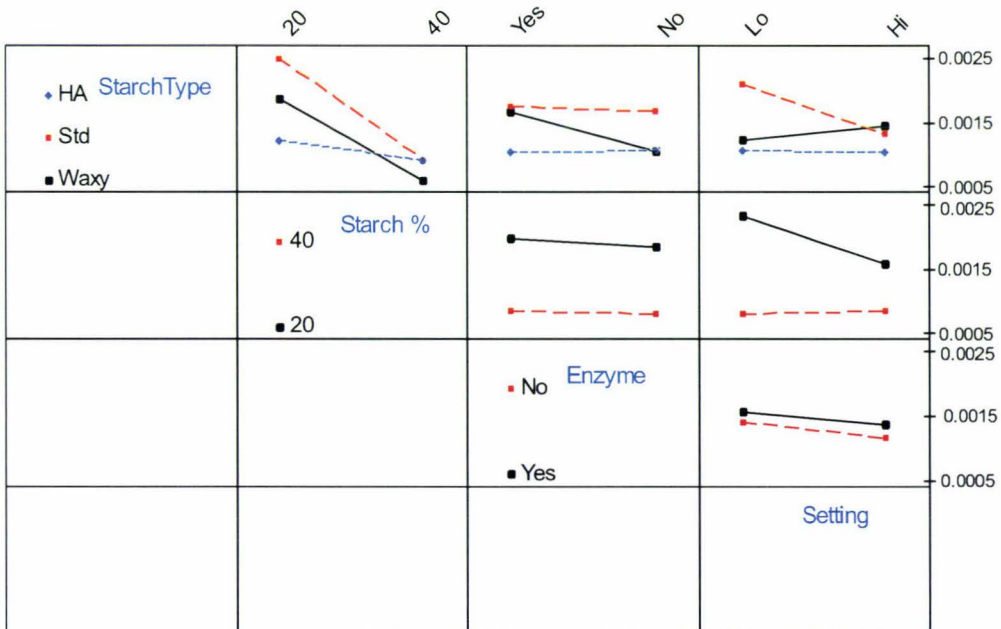


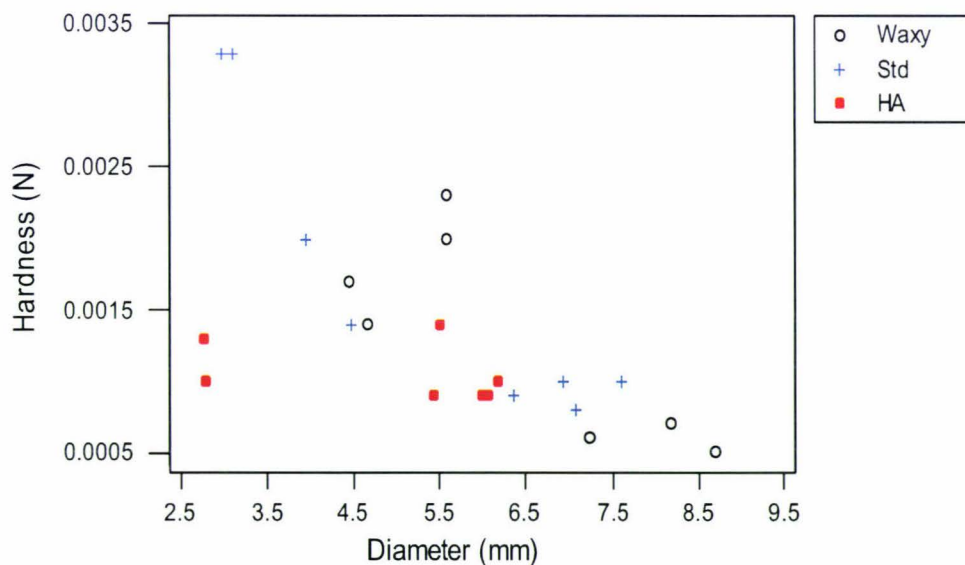
Figure 8.18: Interaction Plot for Effect of Factors on Hardness



There was weak evidence that starch type also had an effect on the hardness of extruded samples ($p=0.077$). Figure 8.18 indicates that standard starch resulted in the hardest extrudates, particularly at the low screw speed setting. Neither the processing conditions ($p=0.175$), nor the enzyme treatment ($p=0.435$) had a significant effect on the hardness of extruded samples. An ANOVA Table for the response 'hardness' is shown in Table 4, **Appendix E-2**

More importantly, hardness was negatively correlated to expansion ($r= -0.66$, $p=0.001$), with hardness decreasing as expansion increased. This correlation is shown by the Table 5, **Appendix-E2**. However, the relationship between expansion and hardness differed for the three starch types. In particular, the high amylose starch appeared to have similar hardness values regardless of expansion, as shown by Figure 8.19.

Figure 8.19: Relationship between Expansion (Diameter) and Hardness by Starch Type



Discussion

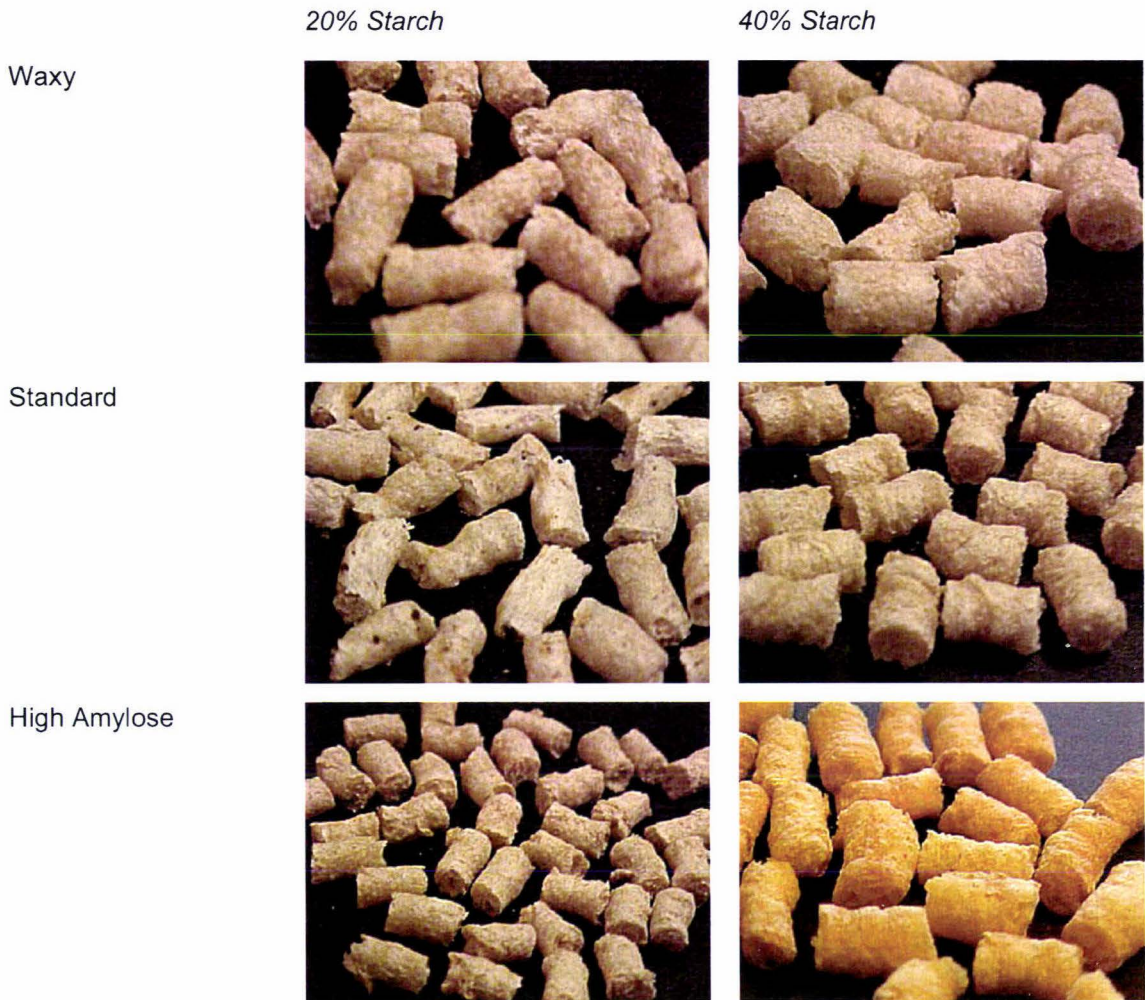
This research showed that extrudate hardness was inversely correlated with expansion with hardness decreasing with extruder factors that favoured expansion. Most significant was the increasing starch level. Liu *et al.*, (2000) also showed that hardness decreased with the addition of corn flour. There was also weak evidence that waxy starch produced the least hard extrudates. Harper and Tribelhorn (1992) reported that

standard and waxy corn produced a brittle texture with low density, whilst high amylose corn produced a chewy extrudate. The instrumental hardness measurements found in this research need to be correlated with the sensory perception of hardness to determine whether panellists could pick up the same effects as indicated by the instrumental measurements.

Appearance

The visual observations of the extrudate appearances confirmed the hardness and expansion objective measurements that were made on the samples.

Photos of all samples may be found in **Appendix E-1**. Selected photos are presented in this section to illustrate the effects of the controlled factors on the appearance of the samples. Samples containing a higher level of starch (40%) were more expanded and samples containing less starch (20%) were more compact as shown by Figure 8.20. The more expanded samples tended to be less variable than moderately expanded samples; very minimally expanded samples were also very regular. More expanded samples tended to have a greater number of air cells on the surface and these air cells tended to be smaller than air cells on moderately expanded samples. The size of the air cells is not adequately depicted in these photographs.

Figure 8.20: Photographs of samples; screw speed 300rpm, no enzyme

Samples containing waxy starch were more expanded and appeared to be more sponge-like than samples containing either standard or high amylose starch (Figure 8.20). Samples containing waxy starch tended to have a more regular (less variable) appearance (Figure 8.20).

The effect of starch level and process setting is illustrated for standard starch in Figure 8.21 below. Standard starch at the low level resulted in samples that were not expanded (low screw speed) or knobby samples with fewer, larger air bubbles. At the higher starch level and low screw speed samples were more regular (similar to waxy starch samples), but at the higher screw speed combination samples have a rougher, snakeskin-like surface.

Figure 8.21: Photographs of extruded samples

Screw Speed
250rpm

20% Starch



40% Starch



300rpm



Discussion

Liu *et al.*, (2000) found that the negative appearance attributes of extrudates such as roughness, compactness, dry surface, curving and irregularity increased with increasing levels of oat flour in an extruded oat-corn puff. Similar negative appearance observations were noted in this research for samples containing a lower level of starch (and hence a higher level of oat flour).

Liu *et al.*, (2000) also reported that screw speed increased attributes associated with a well expanded product (open cell, crispness and shiny). In this research, there was no clear effect of greater expansion and related attributes at the higher screw speed, again, this is likely to be due to the change in conditions not being large enough.

Harper and Tribelhorn (1992) reported that high amylose corn produced a finer structure than standard or waxy corn. Extrudates produced from high amylose corn had very small, evenly sized cells. Extrudates produced from standard and waxy corn had irregular shaped cells. This was in contrast to this research, where waxy starch samples appeared to be more regular.

8.6.2.3. Nutritional Properties

Table 8.9: Results of Factorial Experiment – Nutritional Properties

<i>Run</i>	<i>IDF (dwb)¹</i>	<i>SDF (dwb)¹</i>	<i>TDF (dwb)²</i>	<i>β-Glucan³ (dwb)</i>	<i>Moisture (%)</i>
1					
2				1.35 ± 0.19	9.81
3					
4	4.17 ± 0.16	3.64 ± 0.13	7.80	1.37 ± 0.35	9.72
5					
6				1.26 ± 0.02	10.18
7	2.25	2.57	4.83	1.34 ± 0.04	9.32
8				1.24	11.36
9					
10				1.69 ± 0.17	9.97
11					
12	3.91 ± 0.02	3.93 ± 0.02	7.84	1.57 ± 0.10	9.67
13					9.69
14				1.12 ± 0.08	9.08
15	2.27	1.91	4.18	1.23 ± 0.00	8.82
16				1.27	8.39
17	3.73	1.91	5.63	1.38	8.74
18	3.35	1.92	5.27	1.75 ± 0.02	8.86
19	8.14	4.57	12.27	1.46 ± 0.19	8.34
20	4.38 ± 0.09	3.31 ± 0.26	7.69	1.42	8.08
21	2.79	1.91	4.71	1.38	7.56
22	3.76	3.48	7.24	1.30 ± 0.10	8.98
23	2.39	2.56	4.96	1.38 ± 0.23	9.43
24	2.53	2.44	4.97	2.00	8.69

IDF and SDF samples measured in duplicate are reported as mean $\pm \left(\frac{\max - \min}{2} \right)$

² TDF concentration was determined by addition of IDF and SDF

³ β-glucan samples measured in triplicate are reported as mean (\pm SD). Standard deviations are not reported where single measurements only were made.

Due to unforeseen difficulty in the dietary fibre testing protocol and constraints on the researchers' time, not all testing was able to be fulfilled and there are missing data points for some responses. Duplicate measurements were unable to be completed for dietary fibre testing due to financial and time constraints. The data has been interpreted subject to these constraints. In hindsight it would have been more practical to complete a fractional factorial design or consider fewer factors.

Dietary Fibre

Effect of Extrusion Process on Dietary Fibre Level

Comparison of the dietary fibre contents of the raw ingredients and the extruded samples provided some indication on what effect the extrusion variables had on the various response variable such as IDF, SDF and TDF.

The dietary fibre contents of the ingredient components in the formulation that contributed dietary fibre (oat flour and oat bran) were measured. The fibre content of the starch was assumed to be negligible. The fibre content of the raw material blends were calculated on a dry weight basis, based on their relative proportions in the formulation. The fibre determination calculations and conversion to a dry weight basis were described in section 8.3.1. The calculated dietary fibre contents for the raw blends are shown in Table 8.10 below.

Table 8.10: Dietary Fibre Contents of Raw Material Blends (dry weight basis)

<i>Starch Level</i>	<i>Treatment</i>	<i>IDF (%)</i>	<i>SDF (%)</i>	<i>TDF (%)</i>
20%	Raw Blend	5.28	1.31	6.59
40%	Raw Blend	4.11	1.06	5.17

The percentage change in total, soluble and insoluble dietary fibre content during the extrusion process for the 12 (out of 24) extruded samples analysed is presented in Figures 8.22-8.24 respectively. Each sample represents a run with a different set of processing and/or formulation conditions. Details of the conditions for each run are shown in Table 8.4 in Section 8.2.6.

Figure 8.22 below shows that TDF either increased or decreased during extrusion. The change in total dietary fibre was generally between -20% and +40%. Run 19 produced an extraordinarily high increase in TDF (86%). Run 19 was as a consequence listed as a suspected outlier and has been labelled as such in Figure 8.22. This particular run is also considered to be an outlier in the subsequent comparisons. This run was unable to be repeated due to time constraints.

Figure 8.22: Effect of Extrusion Processing on TDF

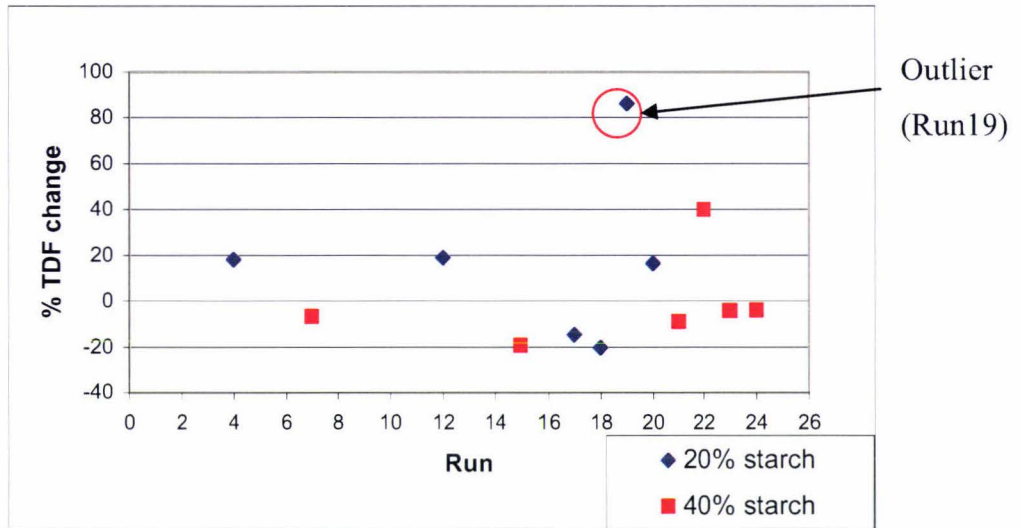


Figure 8.23 below shows that SDF increases by between approximately 50 and 250%.

Figure 8.23: Effect of Extrusion Processing on SDF

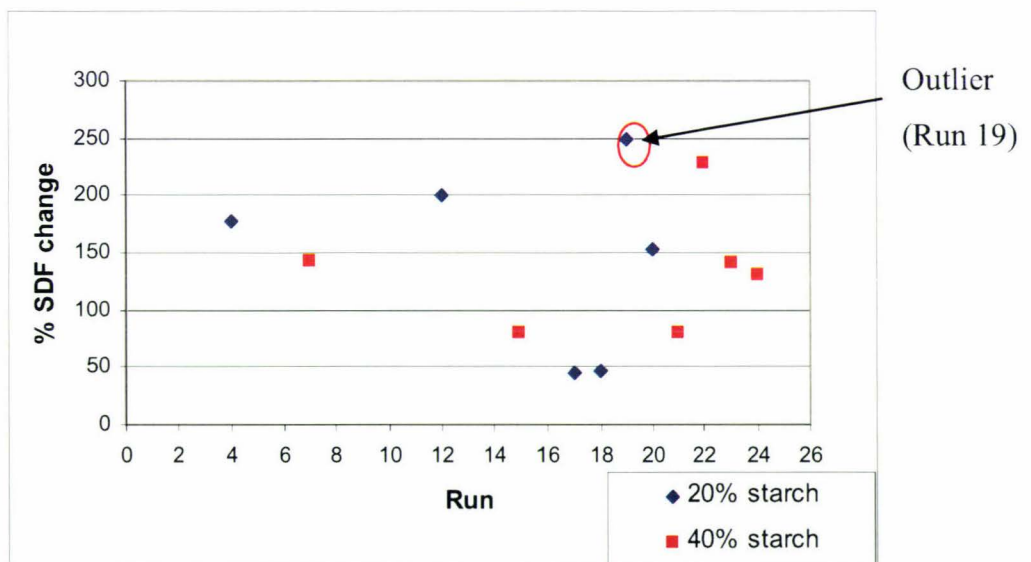
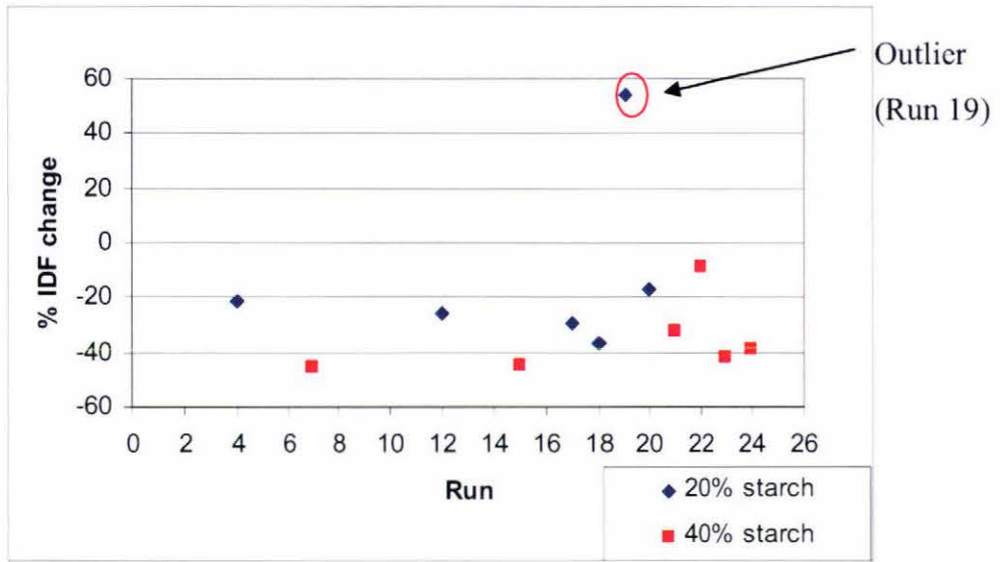


Figure 8.24 below shows that extrusion caused a decrease in IDF of between approximately 10% and 50%, with the exception of Run 19 which resulted in a 54% increase in IDF. Again, it is suspected that Run 19 was an “outlier” and has been labelled as such in Figure 8.24.

Figure 8.24: Effect of Extrusion Processing on IDF

Effect of Factors on Dietary Fibre Level

The dietary fibre results are shown in Table 8.9 above and are analysed in this section. Comparison of extruded samples processed at different process settings, using different starch types and levels, and with and without enzyme treatment provided an indication of the effects of these factors.

Effect on TDF

Figure 8.25: Effect of Factors on TDF

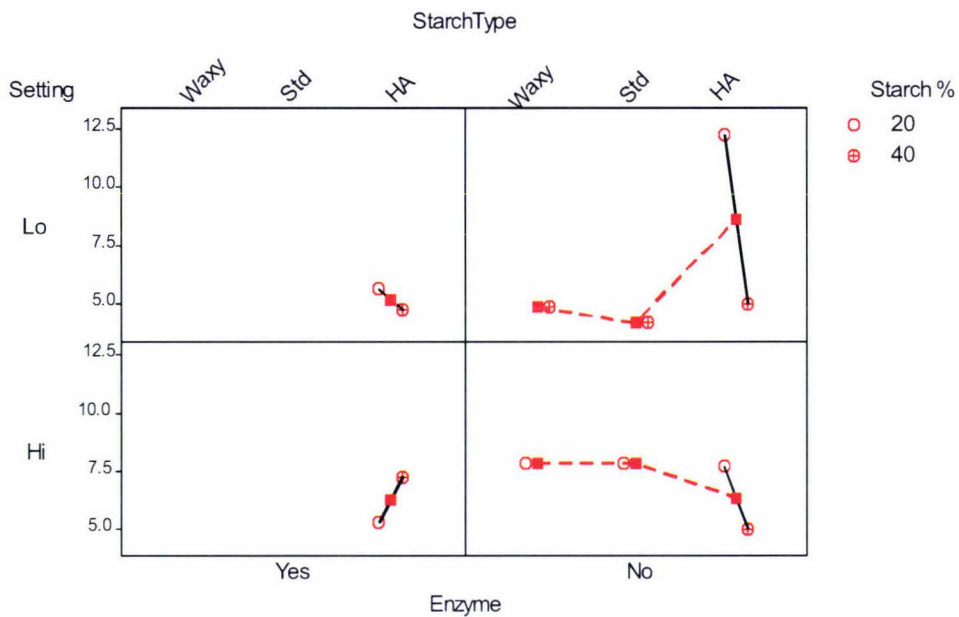


Figure 8.25 shows that starch level appeared to have an effect on total dietary fibre concentrations and this was most apparent in the non-enzyme treated high amylose starch samples. Samples containing 20% starch had higher TDF levels than 40% starch samples, for both high and low settings. This is a logical result considering formulations with lower levels of starch contained higher levels of oat flour which contributes dietary fibre.

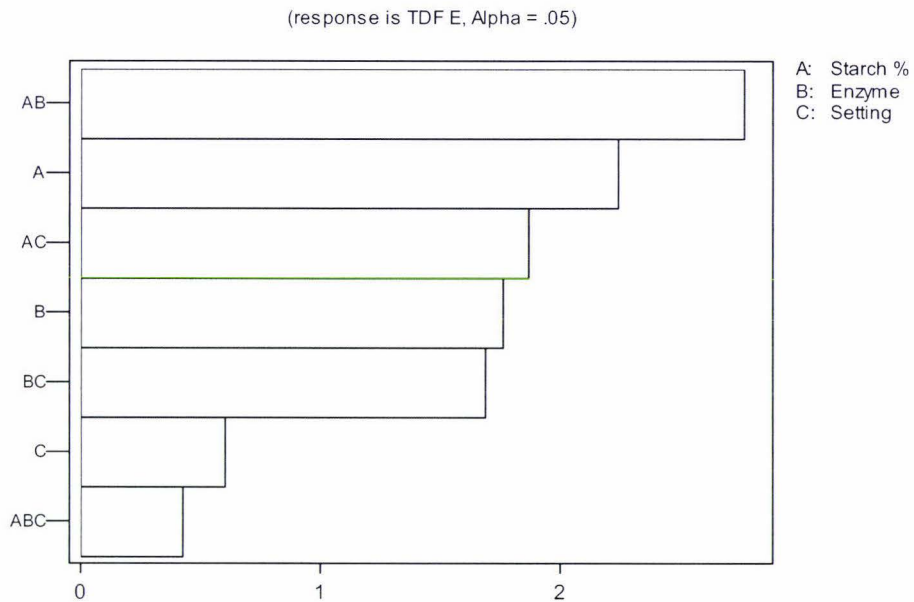
However, varying the starch type had little effect on TDF as illustrated by Figure 8.25. A comparison was made between 20% waxy, standard, and high amylose starches processed at the high setting with no enzyme addition, and another between 40% waxy, standard, and high amylose starches, processed at the low setting without enzyme treatment. These comparisons show that the TDF content for the different starch types was almost identical.

There was no significant difference between enzyme treated and non-treated high amylose starch samples, again, with the exception of high amylose starch processed at

the low screw speed process setting and no enzyme addition. However, it should be noted that the starch level effect seemed to be reversed with enzyme addition. Figure 8.25 shows that samples containing 40% starch samples that had been treated with enzyme and processed at the high setting appeared to have a higher TDF content than 20% starch samples.

The effect of process setting could only be evaluated by comparing the high amylose starch samples processed at the high and low settings. Comparing 40% HA starch samples without enzyme treatment (see Figure 8.25), it appeared that the process setting had no effect. However, this was not the case for the 20% samples (non-enzyme treated), possibly because the 20% sample processed at the low setting resulted in an unusually high value. This observation about process setting needs to be validated with further testing of samples from the remaining 12 runs.

The results obtained for high amylose starch were further analysed as a 2^3 full factorial design. Only high amylose starch samples were analysed because a complete data set was obtained for this starch type, therefore analysis could be completed without confounding. It can be seen from the Pareto chart (shown in Figure 8.26) that the starch-enzyme interaction had the largest effect, and this was followed by starch level. This further confirms the fact that process settings had very little effect on TDF values.

Figure 8.26: Pareto Chart for % TDF (High Amylose Starch 2³ Factorial)

If it is assumed that process settings had little effect on the TDF level (based on the TDF results for 40% HA samples without enzyme addition for which a complete dataset was obtained), then further comparisons can be made between starch type and level without enzyme addition. This assumption was applied to the following analysis of TDF, IDF and SDF.

Figure 8.27 shows that the lower starch percentage led to higher total dietary fibre content for all starch types ($p=0.027$). A Tukey test shows that decreasing the starch level from 40% to 20% increased the TDF by $4.16 (\pm 1.23)\%$. However, the analysis showed that there were no significant differences between different types of starch. The ANOVA table for this two factor factorial with no interaction terms is shown in Table E2-8, **Appendix E-2**.

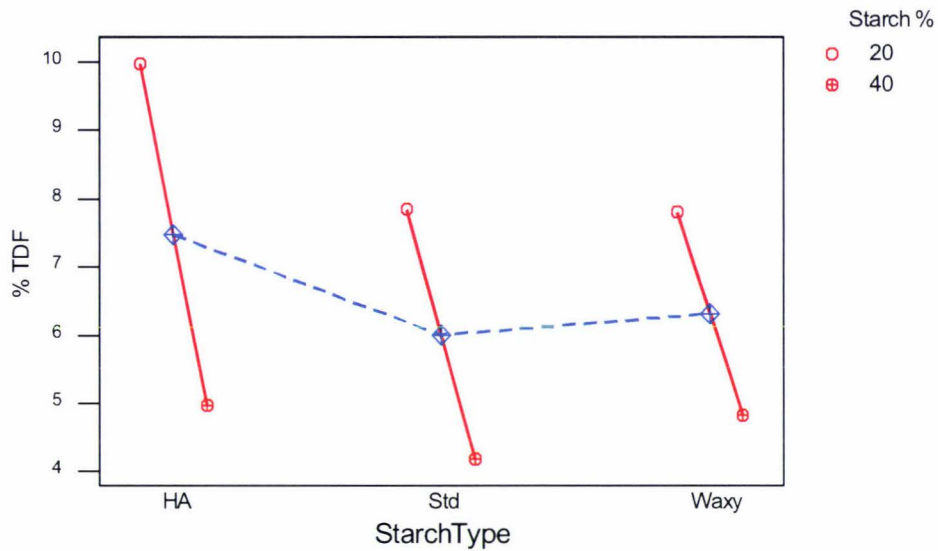
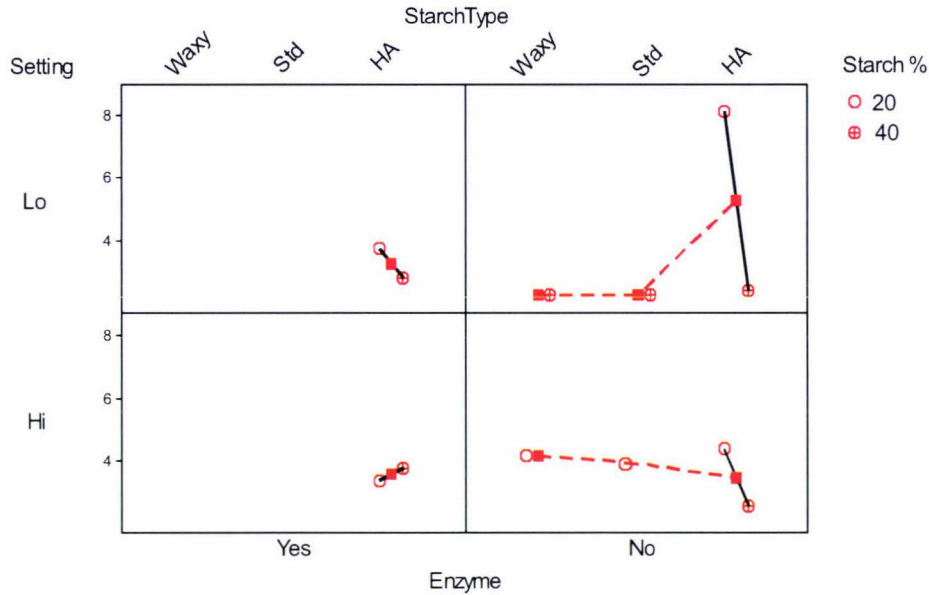
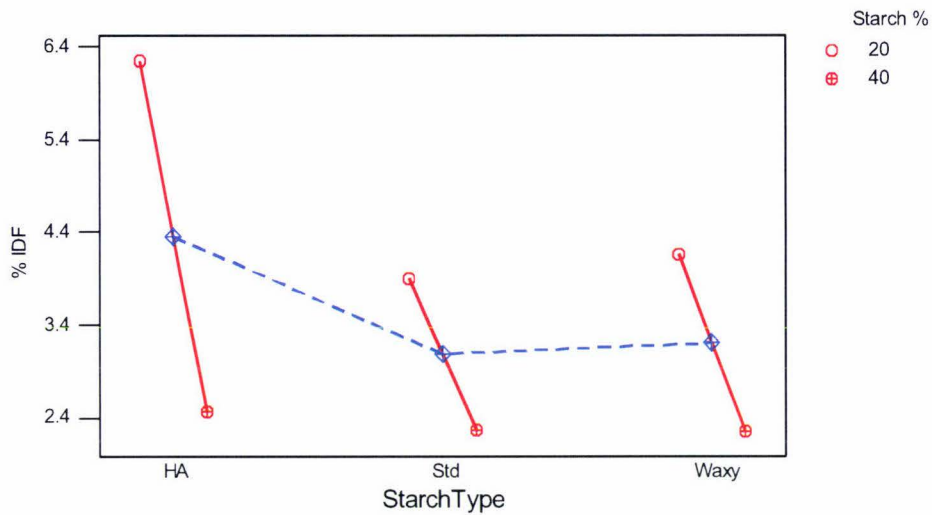
Figure 8.27: Effect of Starch Level and Type on TDF (No Enzyme)**Effect on IDF**

Figure 8.28 illustrates that the trends for IDF are similar to those found for TDF. The process settings and enzyme treatment did not appear to have an effect on the insoluble fibre content, again assuming that the 20% high amylose starch processed at the low setting without enzyme treatment was an unusually high value. This assumption may be justified since if resistant starch was formed using 20% high amylose starch then it would be expected that the effect would occur (and be more pronounced) using 40% high amylose starch.

Figure 8.28: Effect of Factors on % IDF

A model including 2 factor interactions was unable to be fitted due to collinearity, therefore, a model including main effects only was fitted. Analysis of variance of all the IDF data (Table E2-9, **Appendix E2**) showed that starch level was significant at the 10% level ($p=0.053$). Repeating this analysis with the unusually high value removed (Table E2-10, **Appendix E2**) yielded similar significance to the complete dataset model ($p=0.054$).

Assuming that the process setting had no effect, the effect of starch type and starch level was analysed for samples without added starch. The results are illustrated in Figure 8.29 below.

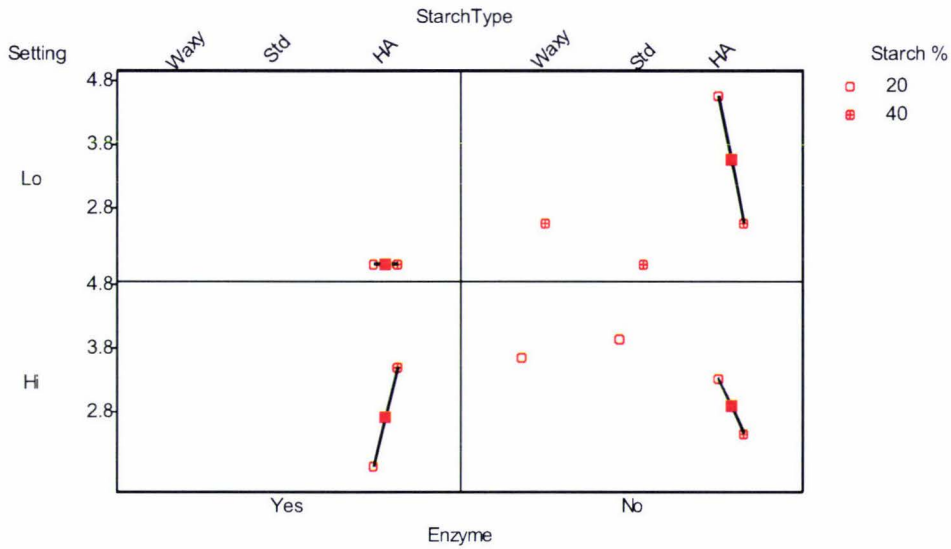
Figure 8.29: Effect of Starch Level and Type on % IDF (No Enzyme)

In this simplified model, where only starch type and level was included in the model and with the outlier removed, showed that starch level had a significant ($p= 0.015$) effect on IDF, but that starch type had no impact on IDF concentrations in the extrudates. Decreasing the level of starch from 40% to 20% resulted in a mean decrease of IDF of $1.50 (\pm 0.41)\%$. The ANOVA table for this simplified IDF model may be found in Table E2-11 (**Appendix E-2**).

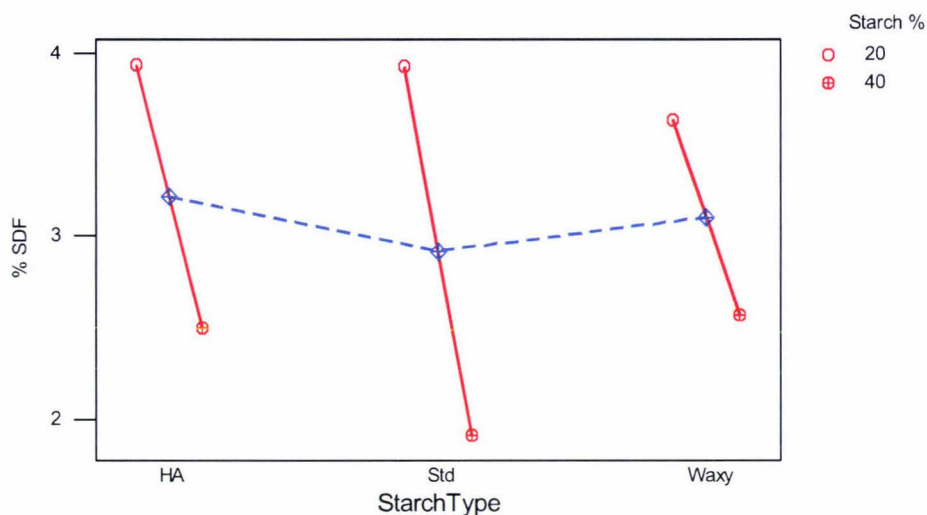
Effect on SDF

Figure 8.30 shows that similar trends were also found for SDF.

Figure 8.30: Effect of Factors on SDF



Considering the results without enzyme treatment only, and assuming that the process setting did not make a difference, the effect of starch level and type can be determined. Based on these assumptions, the ANOVA showed that the starch level had a significant effect ($p=0.014$) for a model including main factors only as shown by Table E2-11 (**Appendix E-2**) and illustrated in Figure 8.31. Decreasing the starch level from 40% to 20% resulted in an increase in percentage SDF of $1.49 (\pm 0.3592)\%$ ($p=0.014$). The type of starch did not have a significant effect on SDF.

Figure 8.31: Effect of Starch Level and Type on SDF (No Enzyme)

Discussion

Overall, the extrusion process was found to increase soluble fibre, decrease insoluble fibre and increase the overall dietary fibre content. This conclusion has been drawn based on a comparison between the calculated fibre content of the raw material blends and the measured dietary fibre contents of the extruded products. The actual fibre content of the raw material blends was not able to be measured due to constraints on the researcher's time and cost constraints on the project. The calculated fibre (IDF, SDF, TDF) contents are based on measured fibre values for oat flour and oat bran. However, measured fibre contents for oat flour were highly variable which indicates a large measurement variation. The fibre determinations made by the researcher should be validated by an independent laboratory to check their validity. Many of the extruded samples were tested without duplicates, the error associated with these values is also unknown.

However, the results from the present project appear to be in agreement with the results reported by other authors. Gaublerto *et al.* (1997) and Wang and Klopfenstein (1993) both found increased soluble dietary fibre in extruded oats. Gaublerto *et al.* (1997) reported an increased soluble fibre content of oats by approximately 32% and reduced insoluble fibre content (between 14.3% and 17.7%). Wang and Klopfenstein (1993) also reported increased total and soluble fibre content in extruded oat grains under certain extrusion conditions with an increase or decrease in the insoluble fibre

depending on the conditions used. A number of other authors have found increases in total and/or soluble fibre for other grains, as outlined in chapter 3.

In this research the insoluble fibre content decreased and soluble fibre content simultaneously increased, this redistribution may be explained by a mechanism proposed by Camire (2001), whereby larger insoluble fibre molecules are sheared during extrusion to form smaller water soluble molecules. However, in this research, the increase in soluble dietary fibre exceeded the decrease in insoluble fibre, which indicated that fibre was also formed from a non-fibre source. Fibre manufactured in this way may be soluble, insoluble or a combination of both. In this instance, it is likely to be mainly soluble fibre that was formed. Therefore, the most likely scenario is that resistant starch (refer to chapter 7, section 7.4.3) was formed by either the starch fraction of oat flour or the maize starch in the formulation. Another effect that could have occurred during extrusion, but the effects were not clearly seen here, was the formation of polysaccharide-lipid complexes. Starch-lipid complexes are analysed as insoluble fibre, and would therefore increase the insoluble and total fibre percentages.

This research showed that the total, soluble and insoluble dietary fibre levels decreased with starch addition. Since starch replaced oat flour in the formulation, this indicated that oat flour contributed more fibre than the resistant starch (if any) was contributed by the starch portion.

It was expected that starch type would have a significant effect on resistant starch formation and hence total and soluble dietary fibre content. Based on the literature it was anticipated that high amylose starch would yield more resistant starch than standard or waxy starches due to a higher amylose content as shown by Unlu and Faller (1998). In addition, it was anticipated that enzyme treatment would further increase resistant starch formation by the hydrolysis of the starch fragments to small linear chains which favoured the formation of resistant starch. However, in this study there were no clear differences in dietary fibre contents between the three starch types used, nor any clear effect of enzyme addition.

The inconsistent effect of the enzyme treatment was hardly surprising, given the relative lack of control in this experiment. In the enzyme modification process, starch slurries

were stirred periodically in a beaker using an overhead stirrer and hence homogeneous temperature was unlikely to be maintained throughout the beaker, this may have effected the enzyme activity. Despite this, an overall increase in resistant starch was expected, but not observed in this study with enzyme treatment. In future, it is recommended that a commercially produced resistant starch is used such as Hi-Maize®.

The conditions varied in this research were screw speed and water feed rate. No change in total or soluble dietary fibre was seen in either of the two process conditions trialled in this research, classed as “low” (screw speed 250rpm, water feed rate 0.24Lh⁻¹) and “High” (screw speed 300rpm, water feed rate 0.108Lh⁻¹). This is in contrast to other authors who have found that processing conditions have a significant effect on the dietary fibre content and solubility. Redistribution of IDF to SDF is generally greater under more extreme process conditions such as high shear and temperature. The effect of screw speed reported in the literature shows contradictory findings. Gaulberto *et al.* (1997) reported that the increase in soluble fibre and decrease in insoluble fibre was lower at higher screw speeds. Other authors cited by Gaulberto *et al.* (1997) have reported the opposite. Wang and Klopfenstein (1993) reported non-linear results for the effect of screw speed on dietary fibre; TDF, SDF and β -glucan contents were optimised at a screw speed of 300rpm and lower contents were found at higher and lower screw speeds.

The lack of difference seen in this research was probably due to the fact that the differences in processing conditions used in the study were not large enough to see any effect. These conditions were purposely selected to provide products with desirable appearance properties. The trial aimed to see whether variations in extruder processing conditions providing a similar amount of torque (an indication of the amount of work) resulted in different nutritional properties, it appears that these different conditions selected had no effect on the DF profiles.

The dietary fibre content of the extruded oat ingredients developed contained a significant amount of dietary fibre compared to other extruded ingredients such as rice bubbles. This fibre content will contribute favourably to a fibre content claim for a snack bar product.

Beta-Glucan

Effect of Extrusion on Beta-Glucan

Comparison of the raw and extruded blends indicated the effect of extrusion processing on the β -glucan content. β -glucan is a form of soluble fibre present in oats. The ingredient components in the formulation that contained β -glucan (oat flour and oat bran) were measured. The β -glucan content of the starch was assumed to be zero. The β -glucan content of the raw material blends were calculated on a dry weight basis, and this was based on their relative proportions in the formulation. The calculations for β -glucan determination and the conversion to dry weight basis were outlined in section 8.3.3. The β -glucan contents for the raw blends containing 20% and 40% starch are shown in Table 8.11 below.

Table 8.11: Beta-Glucan Contents in Raw Blends (dry weight basis)

<i>Starch Level</i>	<i>Treatment</i>	<i>β-Glucan (%)</i>
20%	Raw Blend	2.86
40%	Raw Blend	2.58

The percentage change in β -glucan caused by extrusion processing is shown by Figure 8.32 below.

Figure 8.32: Effect of Extrusion on β -Glucan Content

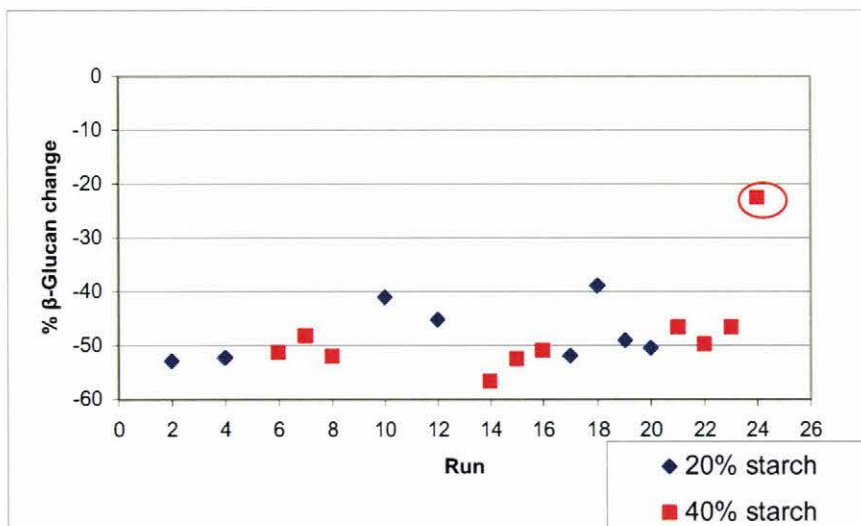


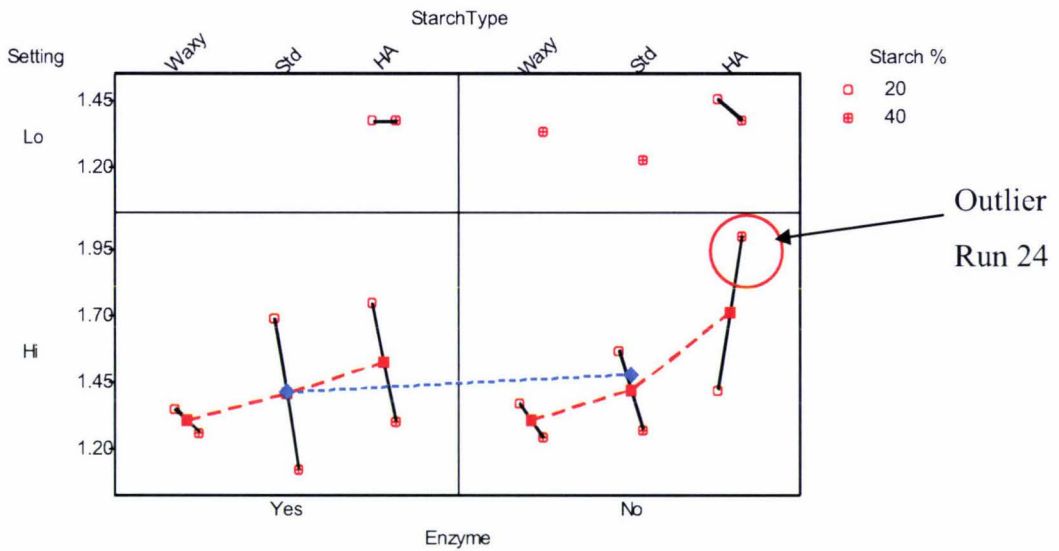
Figure 8.32 shows that there was generally a loss of between 40 and 55% of β -glucan during extrusion processing. The β -glucan loss for run 24 was considerably less (22% loss) than for the other runs. Ideally the run should be repeated to validate the value. However, this was not possible due to budgetary constraints.

Figure 8.32 shows that there was generally a loss of between 40 and 55% of β -glucan during extrusion processing. The β -glucan loss for run 24 was considerably less (22% loss) than for the other runs. Ideally the run should be repeated to validate the value. However, this was not possible due to budgetary constraints.

Effect of Factors on Beta-Glucan Levels

In order to determine how β -glucan could be maximised, the effect of formulation (starch type, starch percentage) and processing (enzyme treatment, extruder setting) variables on the β -glucan content was of interest. The β -glucan determination was not completed for every sample due to constraints on the researchers' time.

The results are presented in Figure 8.33 below. This Figure shows that an unusually high value was obtained for high amylose starch, processed at the high setting without enzyme treatment, this value is labelled in Figure 8.33. Figure 8.33 shows that β -glucan content was generally higher for samples containing less starch.

Figure 8.33: Effect of Factors on β -Glucan content

A model including the main effects and all 2-factor interactions was fitted to the β -glucan data. The ANOVA table (shown in **Appendix E-2**, Table E2-13) shows that there were no significant effects. Therefore, the model was simplified to include only main effects. Analysis of variance on the simplified model (shown in **Appendix E-2**, Table E2-13) still indicated no significant effects, but identified run 24 as an unusual observation. This measurement was deemed to be an “outlier” and removed from the dataset. This particular data point was based on a single measurement only, replication is necessary in order to ascertain its true value. Repeating the analysis after the outlier was removed indicated that the starch level was significant ($p=0.012$) in the simplified model (shown in **Appendix E-2**, Table E2-14), but not the model including interactions. Extruded samples containing 20% starch had a mean β -glucan content of $1.50 (\pm 0.05)\%$ compared to $1.28 (\pm 0.03)\%$ for samples containing 40% starch.

From the testing that has been completed at different process conditions, there were no significant differences between the two process settings used ($p= 0.908$) as shown by Table 3. However, more investigation is required to determine whether a difference exists. Neither starch type nor enzyme treatment had a significant effect on the β -glucan content.

Discussion

In this study, large losses in β -glucan occurred, as seen by a comparison of the raw blends and extruded products. This result is in contrast to other results reported in the literature. Most authors have shown that the total β -glucan content is maintained or enhanced by extrusion processing. Wang and Klopfenstein (1993) reported increased β -glucan levels for extruded oat and barley samples. The effect was found to be non-linear and oat samples extruded under 'medium' (screw speed 300rpm) processing conditions were found to have the highest β -glucan contents. Wang and Klopfenstein also reported that the viscosity and solubility of β -glucan increased during extrusion and have shown that it is beneficial in lowering the cholesterol levels in rats. Gaosong and Vasanthan (2000) also showed that barley beta-glucan contents were generally unchanged, increased or very minimally decreased during extrusion processing.

Huth *et al.* (2000) suggest that the extracted β -glucan content is affected by the feed moisture content more than the mass temperature within the extruder. Samples extruded at lower feed moistures appear to have higher β -glucan contents.

Wang and Klopfenstein (1993) showed that β -glucan content was influenced by screw speed. Water content and screw speed had the greatest impact on the shear force within the extruder, therefore it can be postulated that the β -glucan content was dependent on the amount of shear within the extruder. In this research screw speed and water feed rate combinations were investigated, however no differences in the β -glucan contents were observed. This lack of difference suggests that the processing conditions used in this research did not produce a big enough change in shear to detect the differences in β -glucan that might have otherwise occurred.

Huth *et al.* (2000) suggest that the method of extraction of β -glucan had a big impact on the quantity and properties of β -glucans from barley and other cereals, and complete extraction without degradation was difficult. Huth *et al.* (2000) found the highest amount of β -glucan when extracted at 45°C for 2 hours, the proportion of β -glucans was decreased at higher extraction temperatures. In this study, β -glucan was extracted at 100°C for 5 minutes prior to precipitation with ethanol, this high temperature extraction method may have contributed slightly to the β -glucan loss experienced in this project.

Recommendation

The level of β -glucan contained in the ingredient developed in this project was low, partly due to the low level of β -glucan in the raw materials used, particularly the oat flour, a major component in the formulation and partly due to losses during extrusion. Samples containing 20% starch contained 1.50 (± 0.05)% on average on a dry weight basis, samples with higher levels of starch contained even lower levels of β -glucan which you would expect given the dilution effect of the extra starch and hence lower level of β -glucan.

In order to achieve a significant cholesterol lowering effect an intake of 3g per day is required, and to make a health claim for oat β -glucan in the US a product must contain 0.75g of β -glucan per serve. Assuming this ingredient alone is the sole source of β -glucan, approximately 40g of this ingredient is required per serve to qualify for a heart health claim in the US. This required amount is impractical for addition to a muesli bar without supplementation. The β -glucan content of the extruded ingredient product may be increased in several ways: (1) by selection of raw materials containing higher β -glucan contents (as β -glucan content is influenced by cultivar and milling methods), (2) increasing the proportion of oat bran slightly (to a maximum level without compromising sensory acceptability) and (3) optimisation of extrusion processing conditions such as screw speed and water feed rate.

Other oat ingredients (oat bran, rolled oats) may also be used to increase the amount of β -Glucan in bar products. For example, inclusion of the current extruded oat ingredient at 15% of the formulation, requires supplementation with 4.5% Harraways oat bran (refer to the oat bran spec) to achieve the required level of 0.75g per serve to make a heart health claim in the US.

Research Constraints

The fulfilment of all research objectives was unable to be completed within the timeframe of this project considering the resource allocation available to the researcher. The project brief was of a very broad nature and involved a large amount of preliminary research to determine the direction of the extrusion experimental work and the related analyses undertaken. This preliminary work was vitally important to the commercial

application of the research. This meant however, that the time initially allocated to complete extrusion and analyses was limited to 5 months.

The methodologies for the various nutritional analyses completed in this project were very involved. Completion of training and analyses were extremely time-consuming. The cost of contracting the testing to a technician or accredited laboratory exceeded budget constraints. This placed a great deal of pressure on the researcher's time. Nutritional testing was conducted on product produced from the full factorial design in an attempt to determine the effects of formulation and processing variables on dietary fibre content. These trends were considered to be of greater importance than the final fibre content as full scale production may utilise a different source of oat flour and a different extruder.

In addition to the large volume of testing originally planned, the researcher also encountered unforeseen delays. The researcher had to transfer to another laboratory after initial training and analyses completed in the Massey University Nutrition Lab due to limitations of laboratory access and cost of laboratory use. In completing the transfer, unexpected equipment delays were encountered. The crucibles available to the student were found to be unsuitable after several weeks of trials and delays were encountered whilst new crucibles were made.

In hindsight, the allocation of time would have been better suited to pre-screening of the variables based on physical properties and conducted nutritional analyses on fewer treatments. By doing so, optimisation experiments may have been completed.

This constraint meant that good research practices such as duplicate analyses, repetition of experiments where anomalies or potential outliers occurred were not possible.

8.6.2.4. Summary

Table 8.12: Summary of Effects of Factors on Responses Investigated

	<i>Expansion</i>	<i>Hardness</i>	<i>Appearance</i>	<i>Fibre</i>	<i>B-Glucan</i>
Starch Type	Waxy more expanded than standard or high amylose starch	Weak evidence standard starch harder than waxy and high amylose	Waxy more expanded sponge-like and more regular	No effect	No effect
Increasing Starch %	Increases	Decreases Difference in hardness more pronounced at low screw speed setting and less pronounced with high amylose starch	More expanded and less variable. Greater number and smaller air cells on surface	Decrease TDF, IDF, SDF	Decrease
Enzyme	No effect	No effect	No effect	Inconsistent effect	No effect
Higher Screw Speed (lower water) setting	No effect. Weak evidence of more sample variability	No effect	No effect	No effect	No effect

8.6.2.5. Optimisation

This research was intended to provide information about the effect of formulation and processing treatments (enzyme treatment, and extrusion processing) on selected nutritional properties related to heart health (dietary fibre concentration, β -glucan concentration) and physical and textural properties that are related to the sensory perception of texture. The findings were to be applied to the development of an extruded “functional” oat ingredient that would be rich in β -glucan and soluble dietary fibre (to provide heart health benefits) and to provide desirable textural attributes when used in a cereal bar formulation. The β -glucan content was important for reasons of heart health efficacy and in order to make a health claim in the United States. The soluble dietary fibre content contributes to a heart health benefit.

Therefore, the main parameters to optimise were the β -glucan concentration, soluble dietary fibre concentration and texture. Since the consumer’s perception was unknown, but expansion is related to the instrumental texture measurements, expansion (diameter)

would be used for the purpose of this optimisation. A diameter of approximately 4-6mm appeared to be most suitable.

The optimal formulation and processing conditions were to provide the highest soluble dietary fibre content, β -glucan content and have a diameter of approximately 4-6mm. The samples with the highest SDF values that met this diameter criteria were the samples outlined in Figure 8.34 below. These samples all contained 20% starch, were not treated with enzyme and were processed at the high screw speed extruder setting. An even higher level of SDF was obtained for the 20% high amylose starch samples processed at the low screw speed extruder setting, however as only limited quantities of these samples were collected, no diameter measurement were recorded. More investigation is required to determine the effect of these extruder process settings on expansion and the reproducibility of SDF content.

Figure 8.34: Optimisation of Expansion and % SDF

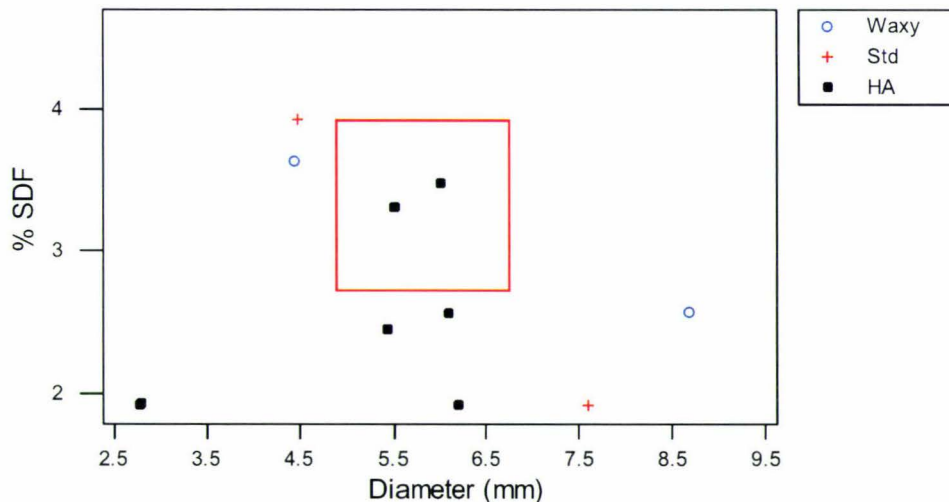
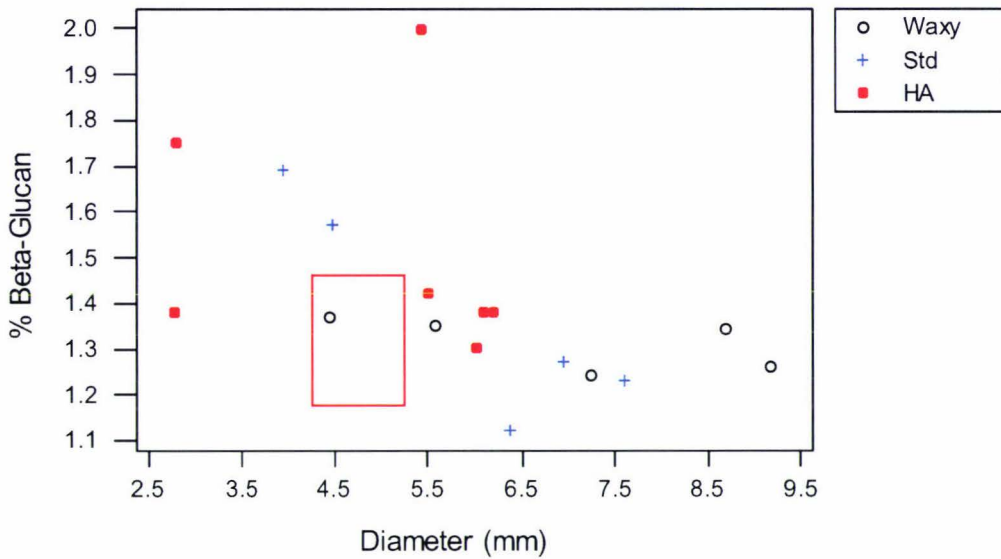


Figure 8.35 below indicates that the highest levels of beta-glucan were achieved in the 20% standard starch samples processed at the high extruder setting (screw speed: 300rpm, water feed rate: 0.108Lh^{-1}), with or without enzyme addition.

Figure 8.35: Optimisation of expansion and β -Glucan

8.6.2.6. Conclusion

Prototype extruded oat based ingredients were produced in a range of diameters, some of which would have potential application in cereal bars. Such extruded ingredients would provide a unique point of difference as a cereal bar inclusion and would be nutritionally superior to rice bubbles.

The extruder settings used in this research had a positive effect on the dietary fibre profile of extrudates produced from oat flour, bran and starch blends by markedly increasing the amount of soluble fibre and moderately decreasing the amount of insoluble fibre. in the extrudates. However, in contrast, β -glucan content was greatly reduced during processing and/or subsequent storage. Soluble fibre has been shown to have a cholesterol lowering effect in humans. In oats, it is β -glucan, a specific form of soluble fibre, that has been shown to provide a cholesterol lowering effect. On a soluble dietary fibre basis extrusion processing technology appeared to be beneficial in that it increased soluble fibre content of the extrudate and hence should provide consumers with added health benefits compared to non-extruded oats. Slight increases in total dietary fibre also provide an advantage for nutrition labelling and will contribute towards dietary fibre levels required to make nutrition claims on finished products that incorporate these extrudates. However, because extrusion and or storage contributed to

a reduction in β -glucan levels, the specific soluble fibre in oats supposedly responsible for oats' health benefits, it is doubtful whether the health benefits of increasing soluble fibre can be claimed for this product. It is recommended that β -glucan testing is repeated on freshly produced samples to eliminate any changes that may occur during storage. Investigation into the extraction temperature used in the analysis of β -glucan should also be considered as a possible cause of the lower β -glucan contents found in extruded samples.

The level of starch included in the formulation (with additional starch replacing oat flour) had the greatest effect on TDF, SDF, IDF and β -glucan contents. A higher level of starch (and hence lower level of oat flour) resulted in lower TDF, SDF, IDF and β -glucan contents. Preliminary trials also suggested that oat bran increased dietary fibre levels.

In order to maximise the amount of dietary fibre (SDF, IDF and TDF) and β -glucan in the extruded ingredient, as little starch as possible should be used and the level of oat bran should be maximised, whilst retaining suitable sensory properties.

There did not appear to be any difference in dietary fibre contents between products extruded on the 'low' and 'high' extruder settings used in this research. The effect of different extrusion processing conditions requires further investigation and optimisation with greater changes being made to extruder settings between extrusion runs to confirm this finding.

Neither the type of starch nor starch enzyme treatment had an effect on the dietary fibre (TDF, SFF and IDF) or β -glucan contents. Therefore, it is recommend that the starch type be selected based on the effect it has on expansion and textural attributes only.

The level of starch had the greatest effect on the expansion of extruded products. Blends containing 40% starch had a 2.92mm greater diameter compared to samples containing 20% starch. The type of starch was also significant with waxy starch producing the most expanded products. It is recommended that waxy starch be used in future trials.

In order to optimise the SDF, β -glucan and expansion, a starch level of approximately 20% is required. More experimentation of the exact starch level necessary to achieve a suitable level of expansion and sensory acceptance in bar products is required.

9. CONCLUSIONS AND RECOMMENDATIONS

9.1 Summary of work conducted and conclusions

The main aim of this project was to develop an extruded ingredient to be used in a range of healthy heart muesli bars to be used by Nice and Natural. First a suitable material was identified taking into account heart health benefits, consumer understanding and acceptance, regulatory restrictions and positive product claims that could be made on products containing the extruded ingredient including endorsements by the New Zealand Heart Foundation, together with the effect that extrusion processing would have on a number of materials that possessed heart health benefits.

Research was then conducted on the chosen material to investigate formulation and extrusion parameters that would impact on the nutritional and physical properties of the proposed extruded ingredient.

Soluble oat fibre was chosen as the ingredient, following is a brief summary of the major findings from the literature review and focus group study that support the selection of soluble oat fibre. Following that is discussion of the extrusion investigation and recommendations regarding the development and marketing of a product using the extrudate.

Market

The functional foods market may provide an opportunity to earn higher profit margins than the traditional food market sectors for the food manufacturer. A gap exists to market a cereal bar that provides heart health benefits in New Zealand and Australia. Another export market of significant potential for this product is the US, due to a combination of its size, high level of interest in heart health and the presence of FDA approved heart health claims.

A market survey was conducted to evaluate heart health bars and cereal products that are currently available or have been marketed in the past. Active components in these products included plant sterol esters, oat beta-glucan, soy protein, folate, antioxidants, psyllium, L-arginine and phytoestrogens. As these products were marketed in the US,

UK and Europe, where health claims are permitted, claims such as “helps lower cholesterol” have been made on pack.

Products that have been most successful are those that have leveraged hidden assets of products that are already well established and competitively priced, or at the other end of the spectrum, are very unique, emphasise the value of well-being, have a long-term commitment to consumer education and carry a greater premium. Many products have failed where health benefit was the only unique selling point and other important consumer needs were neglected, namely good taste, attractive packaging and affordable price.

In devising a market strategy product attributes (including taste, texture, convenience and social acceptance), efficacy, safety and health claims and promotional issues, such as branding, positioning, and communication, all need to be addressed.

Nutrition

A wide range of compounds have been associated with decreasing risk of heart disease, including soluble dietary fibre, mono- and polyunsaturated (omega-3) fatty acids, phytosterols, soya, folate and antioxidant (vitamin E) which were reviewed in this thesis. The degree of evidence available to support the benefits of these compounds varies, as do the amounts required and the population that would benefit most.

Dietary fibre and soy protein are the most practical nutrients to include in an extruded ingredient as their benefits are maintained with extrusion, and there are indications that the nutritional benefit of dietary fibre could actually be enhanced by extrusion. Lipids, folic acid and antioxidants would be degraded during the extrusion operation and therefore should be included in post extrusion processes if required.

Regulations

All ingredients reviewed may be added to food products under the FSANZ food regulations. However, plant sterols are only permitted in fat based spreads and vitamins (folate, vitamin E) may only be added to breakfast cereals or to products regulated under the FSANZ dietary supplements or meal replacement regulations. In New Zealand, no heart health claims are permitted, only nutrient content claims may be used.

Products may be endorsed by the National Heart Foundation under their licensed “Pick the Tick” program if conditions are met. In the US, a number of heart health claims are permitted.

Consumer

There was a high awareness among focus group participants of dietary fibre (no awareness or differentiation between soluble and insoluble forms), fat (concerned about total fat), omega-3 and salt. There was a low awareness or negative impression of plant source of omega-3, psyllium, soy, plant sterols, folate and antioxidants.

A muesli bar was considered to be an appropriate heart health product. According to the groups surveyed such a product should be low in fat, high in fibre, contain omega-3 and most importantly should be endorsed by the National Heart Foundation, (i.e. carry the NHF Tick) in addition to the prerequisites of good taste, reasonable pricing and other important factors in a snack such as sustained energy.

Screening

Probability screening was conducted based on the following screening criteria: health benefit, positive consumer awareness, acceptability in a muesli bar, processing and stability, regulations and cost. Probability screening scored the nutrients investigated in the following order (from most to least favourable): soluble fibre, plant sterols, soy protein, omega- 3, monounsaturated fatty acids, folate, vitamin E. Based on this result it was decided that the extruded ingredient should contain soluble fibre. The source of soluble fibre selected was oat due to health claim advantages in the US, positive consumer awareness and low cost.

Investigation of the effect of important formulation and processing parameters on the nutritional and physical properties of an extruded oat ingredient rich in soluble dietary fibre and β -glucan

Extrusion

Extruded oat prototype ingredients rich in soluble fibre were produced and the effect of the formulation and extrusion processing conditions on the nutritional and physical properties were investigated. It is the dietary fibre content and solubility and the β -

glucan content that is of interest as these properties influence the heart health benefits and claims that can be made with respect to heart health. The physical properties of interest were expansion and hardness as these properties are related to texture. The sensory properties of the ingredient were not tested since it is the sensory perception within the final product format that is important.

Nutritional properties

Extrusion processing had a positive effect on the dietary fibre profile of oat flour, bran and starch blends under the conditions tested in this research. Soluble dietary fibre was markedly increased and insoluble fibre was moderately decreased during the process. However, the β -glucan content, a particular form of soluble fibre in oats that has been recognised to lower serum cholesterol, was greatly reduced during processing and/or subsequent storage. It is unclear whether the health benefits of oat blends were improved or reduced by extrusion.

The effect of various formulation and processing variables on dietary fibre and β -glucan content has been shown.

Addition of oat bran to replace oat flour increased IDF, SDF and TDF due to the higher fibre content in bran compared to flour. Addition of starch decreases IDF, SDF, TDF and β -glucan. The starch level is the most significant factor. The type of starch used has no effect on the dietary fibre or β -glucan content. Neither enzyme treatment nor extruder setting had an effect on dietary fibre or β -glucan levels.

Physical properties

The starch level had the most significant effect on the physical properties, expansion and hardness. Increasing the starch level increased product expansion and decreased hardness. Expansion and hardness were related (negative correlation).

Starch type also has an effect on expansion and hardness. Waxy starch produces more expanded extrudates than standard or high amylose starch. The appearance supports the expansion results, with waxy samples appearing more expanded, sponge-like and regular.

Neither enzyme treatment, nor extruder processing settings had a significant effect on the physical properties in this research.

Formulations containing 20% starch, 20% oat bran and 60% oat flour were found to provide sufficient expansion.

Overall Achievements

Beneficial and desirable nutrients to include in an extruded ingredient possessing heart health properties were determined. An extruded ingredient rich in oat soluble fibre, is unique and will provide significant competitive advantage to Nice and Natural for use in their muesli bars. Such an ingredient can be used to replace rice bubbles in formulations and provide superior nutritional properties.

Numerous prototype extruded ingredients were produced. The suitability of various oat ingredients was tested and narrowed down to oat flour, oat bran and added starch.

The effect of formulation and processing variables on fibre content, β -glucan content, expansion, hardness and appearance was shown.

Prototype extruded ingredients with acceptable levels of expansion and appearance were produced.

The extruded ingredients produced contained lower levels of β -glucan and increased dietary fibre levels compared to the blends that they were produced from. It is unclear whether the extrusion process has improved or reduced the cholesterol lowering properties of the raw materials and clinical human trials or suitable animal studies would be needed to elucidate the effects of these processing conditions on the cholesterol reducing properties of the extrudates.

Whilst an optimised ingredient has not been produced within the scope of this research due to the time and financial constraints, the information obtained will prove useful in the further development and optimisation.

Further development of this ingredient is required, recommendations are given.

9.2 Recommendations for future work

9.2.1. Ingredient Development

Ingredient formulation

In order to maximise the amount of dietary fibre (SDF, IDF and TDF) and β -glucan in the extruded ingredient, as little starch as possible should be used and the level of oat bran should be maximised, whilst retaining suitable sensory properties. Further experimentation is recommended to optimise the formulation with respect to dietary fibre and β -glucan, and expansion which provides an acceptable sensory characteristic.

Ingredient Source

Oat Bran

The oat bran used in this experimental work had a β -glucan content of approximately 12% which is lower than overseas oat brans. Oat bran concentrates with higher β -glucan contents (up to 22%) have become available through New Zealand distributors since the commencement of this research. The effect of the use of these ingredients on nutritional and physical properties should be investigated.

Starch

In this experimental work, attempt was made to produce resistant starch via enzyme treatment and subsequent extrusion processing, which had limited success. Further experimentation using the commercially available Hi-maize® resistant starch, is recommended. Hi-maize® starch may contribute to a higher dietary fibre level.

Extruder Processing Settings

In this research the extrusion processing settings used were too similar to result in a detectable difference in the physical and nutritional properties of extrudates. More drastic changes in process settings are recommended. In addition, the extruder process settings were confounded as screw speed and water feed rate were altered simultaneously. Investigation of the effect of individual process settings is recommended.

9.2.2. Related Research

Several related research topics are suggested for future investigation;

1. Investigate the effect of extrusion processing on the viscosity of oat β -glucan under the conditions used to produce the ingredient developed. The viscosity of β -glucan is another factor related to the heart health benefit
2. Conduct clinical studies to compare the health benefit of raw and extruded blends to determine the health significance of increased dietary fibre levels by extrusion processing. Conduct clinical studies on products containing the extruded ingredients to determine the health significance of the products.
3. Compare the nutritional and physical properties of products produced from oat and barley. Barley contains high levels of β -glucan.
4. Conduct large scale quantitative consumer research on consumers understanding and perception of functional food ingredients and products.
5. Investigate consumer motivation to purchase functional foods based on “life marketing” (positive health messages) vs “death marketing” (fear of dying).

9.2.3. Feasibility for Ingredient Commercialisation

A cost analysis to produce the ingredients should be conducted. Cost of producing the extruded oat ingredients using standard oat brans and oat bran concentrates (high β -glucan) should be compared, as should the cost of using standard starch compared to Hi-maize starch®. The most economical option to produce claimable levels of β -glucan, based on the combined β -glucan content of the extruded ingredients and bar supplementation, should be determined and weighed up against sensory factors.

The health benefits and economic benefits of producing the extruded oat ingredients developed in this research and in future work on this project should be compared to other ingredients that are available on the market to ascertain the feasibility of commercialisation.

9.2.4. Production and Scale-up

In the mid-term it is recommended that the ingredients are contract manufactured by Massey University using the extruder used in this research. Should further extruded ingredients be developed by Nice and Natural Ltd., volumes may warrant extruder purchase. An economic feasibility analysis should be conducted at this point.

Manufacturing the extruded ingredients on a commercial scale extruder requires scale-up design. It is recommended that extruder scale-up design be conducted in conjunction with Massey University.

9.3 Future Development of Snack Bar product

The ingredient developed in this research was intended primarily for use in a snack bar product that provides heart health benefits. Recommendations for the development of the bar are given here.

9.3.1. Formulation

Fibre and β -glucan Supplementation Requirements

The level of β -glucan contained in the ingredient developed is low. If this ingredient is the sole source of β -glucan, approximately 40g of this ingredient is required per serve to qualify for a heart health claim in the US. This amount is impractical for addition to a muesli bar and therefore supplementation with oat bran is required. The amount of supplementation required will depend on the β -glucan levels in the final extruded ingredient and the level the ingredient is used in the bar formulation.

Other Requirements

The bar should be developed to meet the new National Heart Foundation guidelines (due to be released this year) and be endorsed by the Heart Foundation under the Tick program.

Saturated Fat

Low saturated fat levels in the bar product developed are recommended. Fat levels should meet Heart Foundation guidelines.

Omega-3

The addition of omega-3 polyunsaturated fatty acids to the bar formulation is recommended. It is preferable to add a marine source of *n-3* oil as this provides a greater benefit than plant sources of omega-3. However, sensory and shelf life trials comparing the usage of marine and plant sources of omega-3 are recommended.

Plant Sterols

Should future amendments to FSANZ regulations permit the addition of plant sterols to cereal bars, it is recommended that a bar containing plant sterols is developed. Marketing pertaining to plant sterols should be emphasise health rather than heart disease.

9.3.2. Sensory Analysis

It is recommended that sensory analysis be conducted on bar products containing the ingredients and correlations made between physical measurements on the ingredients and sensory scores in the bar. It is the consumer acceptability of the ingredients in bar products that is important since this is how the ingredients are consumed.

9.3.3. Commercialisation of Snack Bar Product

9.3.3.1. Consumer research

New Zealand Market

Once the development the bar product has been completed, it is recommended that product evaluation be conducted on the target market, to test the sensory and brand appeal. Sensory and product evaluation of the final bar is recommended. Evaluation should be conducted on the target market and may be conducted via the same channels as the consumer research conducted in this research.

US

It is recommended that this product be exported to the US. However, it is recommended that further research into the consumer understanding and consumer needs of the US market be conducted before developing and marketing this product in the United States as consumer attitudes vary greatly between countries.

9.3.3.2. Manufacture

It is recommended that the snack bar product be manufactured by Nice and Natural Ltd using current manufacturing capabilities.

9.3.3.3. Marketing

It is recommended that a heart healthy bar be marketed from a “Life Marketing” perspective. The message should be a positive lifestyle message and emphasise well-being and good taste rather than prescribing heart health as the primary focus. The brand name of the product should reflect this. The heart benefit should be incorporated into the wellness concept. The heart benefit should be supported by the use of the NHF Tick.

9.4 Summary

In summary, the development of a functional ingredient requires balancing of many requirements including consumer acceptance, regulatory constraints, health benefits of raw materials and the effect of processing on health benefits and physical characteristics. Development of a muesli bar with heart health benefits will require attention to formulation and dosage of functional ingredients in order to be able to make nutrition or health claims and meet Heart Tick criteria as well as sensory requirements required for the success of any product. Successful commercialisation will also require an effective marketing strategy to be employed.

10. REFERENCES

1. Ahindra, N. A. G. 2000. "Stabilization of flaxseed oil with capsicum antioxidant." *Journal of the American Oil Chemists Society* 77, no. 7: 799-800.
2. Allman-Farinelli, M. (Ed.) 1999. "A review of the relationship between dietary fat and cardiovascular disease." *Australian Journal of Nutrition and Dietetics* 56, no. 4 Suppl: 22.
3. Anderson, J.W., Gilinsky, N.H, Deakins, D.A., Smith, S.F, O'Neal, D.S, Dillon, D.W and Oeltgen, P.R. 1991. "Lipid responses of hypercholesterolemic men to oat-bran and wheat-bran intake." *American Society for Clinical Nutrition*, 54, 678.
4. Anderson, J.W., Riddel-Mason, S., Gustafson, N.J., Smith, S.F and Mackey, M. 1992. "Cholesterol lowering effects of psyllium-enriched cereal as an adjunct to a prudent diet in the treatment of mild to moderate hypercholesterolemia." *American Journal of Clinical Nutrition*, 56, 93.
5. Anderson, J.W., Smith, B.M and Gustafson, N.J. 1994. "Health benefits and practical aspects of high-fiber diets." *American society for clinical nutrition*, 59, 1242S.
6. Anon., 2001. "Promise unfilled". *Functional foods Foodwire*. LLC.
7. Anon. 2002a. "Heart health becomes an everyday marketing message." Online. Microsoft explorer, 4/12/2002. Available:
<http://www.new-nutrition.com/newspage/060401xx.htm>
8. Anon. 2002b. "So how big is the market for functional foods and beverages." Online. Microsoft explorer, 4/12/2002. Available:
<http://www.new-nutrition.com/newspage/6com.htm>
9. ANZFA, 1995. "Code of Practice Nutrient Content Claims in food labels and in advertisements" Australia New Zealand Food Authority. 29p. Available:
http://www.foodstandards.gov.au/_srcfiles/Code_of_Practice_jan1995.pdf
10. ANZFA, 2001a. "Phytosterol esters derived from Vegetable Oils." *Australia New Zealand Food Act*, A410.
11. ANZFA, 2001b. "Tall oil non-esterified phytosterols derived from tall oils." *Australia New Zealand Food Act*, A417.

12. Aoe, S., Nakaoka, M., Ido, K., Tamai, Y., Ohta, F. and Ayano, Y. 1989. "Availability of dietary fiber in extruded wheat bran and apparent digestibility in rats of coexisting nutrients." *Cereal Chemistry*, 252.
13. Artz, W.E., Warren, C., Villota, R. 1990. "Twin-screw extrusion modification of a corn fiber and corn starch extruded blend." *Journal of Food Science*, 55 (3), 746.
14. Asp, N.-G. 1987. "What happens to different materials at different temperatures?." In O'Connor, C., Editor. *Extrusion Technology for the Food Industry*. Elsevier Applied Science Publishers Ltd, Essex.
15. Barclay, W. and Van Elswyk, M. 2000. "Natural enrichment of foods with DHA Omega-3 from golden marine algae." *Functional Foods*, 60.
16. Bell S., Goldman, V.M., Bistran, B.R., Arnold, A.H., Ostraoff, G. and Forse, R.A. 1999. "Effect of B-Glucan from oats and yeast on Serum Lipids." *Clinical reviews in Food science and Nutrition*, 39, 189.
17. Beltoft, A. 2000. "Successful marketing of probiotics." In Angus F. and Miller C. *Functional Foods 2000*. Leatherhead Publishing. p. 367 – 370.
18. Björck, I. and Asp, N. G., 1983. "The Effects of Extrusion Cooking on Nutritional Value - A Literature Review." *Journal of Food Engineering*, 2 (4), 281.
19. Björck, I., Nyman, M., Asp, N.-G., 1984. "Extrusion Cooking and Dietary Fiber: Effects on Dietary Fiber Content and on Degradation in the Rat Intestinal Tract." *Cereal Chemistry*, 61 (2), 174.
20. Blume, M. 2003. "Tick Program Consumer Insights & Communications Planning 2002/2003." CD –Rom. National Heart Foundation. Available: maryke.blume@heartfoundation.com.au
21. Briscoe, G. 2002. Roche. *Personnel communication*. Shelf life of cereal bars containing encapsulated omega-3 fatty acids.
22. Brouns F., 2000 "Soya-based ingredients for the Health-foods market." In Angus, F. and Miller, C. *Functional Foods 2000*. Leatherhead publishing. P.67-78.
23. Brown, L., Rosner, B, Willett, W. and Sacks F.M. 1999 "Cholesterol-lowering effects of dietary fiber: a meta analysis." *American society for Clinical Nutrition*, 69, 30.
24. Brumovsky, J.O. and Thompson, D.B. 2001. "Production of boiling-stable granular resistant starch by partial acid hydrolysis and hydrothermal of high-amylose maize starch." *Cereal Chemistry*, 78, 680.

25. Buitelaar, N. 2000. "Functional Foods: An investors view." In Angus F. and Miller C. *Functional Foods 2000*. Leatherhead Publishing.p.430-435.
26. Camire, 2000. "Chemical and Nutritional Changes in Food during Extrusion." In Riaz, M.N. *Extruders in food applications*. Technomic Publishing Co., Lancaster, Pennsylvania p.127-147.
27. Camire, M. E., Camire, A. and K. Krumhar. 1990. "Chemical and nutritional changes in foods during extrusion." *CRC Critical Reviews in Food Science & Nutrition* 29, no. 1: 35-57.
28. Camire, M.E. 2001 "Extrusion and Nutritional Quality". In Guy, R. Ed. *Extrusion cooking technologies and applications*. Woodhead Publishing Limited, Cambridge, p108-129.
29. Camire, M.E. and Flint, S.I., 1991. "Thermal Processing Effects on Dietary Fiber Composition and Hydration Capacity in Corn Meal, Oat Meal and Potato Peels." *Cereal Chemistry*, 68 (6), 645.
30. Camire, M.E. and King, C.C. 1991. "Protein and fiber supplementation effects on extruded cornmeal snack quality." *Journal of food science*, 56, 3.
31. Campanella, O. and Shah, A.J. 1997. "Extrusion in the Food Industry – A Training Workshop." Department of Food Technology, Massey University, Palmerston North, 96p.
32. Carroll, K.K. 1991. "Review of Clinical studies on cholesterol-lowering response to soy protein." *Journal of American Dietetic Association*, 91, 7, 820.
33. Carter, J. F. 1993. "Potential of flaxseed and flaxseed oil in baked goods and other products in human nutrition." *Cereal Foods World* 38, no. 10: 753-59.
34. Chapman, N. 2000. "New Health claim for plant esters." *Journal of prepared foods*, 169, 11, 24.
35. Cheftel, J.C.1986. "Nutritional Effects of Extrusion-cooking." *Food Chemistry*, 20, 263.
36. Childs. N.M. 2001. "Marketing Issues for Functional foods and Nutraceuticals." In Wildman, R.E.C. *Handbook of Nutraceuticals and Functional Foods*, 1st ed., Lewis Publishers Inc. p.517-528.
37. Conway, H.F. and Anderson, R.A. 1973. "Protein-fortified extruded food products." *Cereal Science today*, 18, 4, 94.

38. Coussement, P., 2000. "Communicating about gut health to the consumer." In Angus F. and Miller C. *Functional Foods 2000*. Leatherhead Publishing. p. 362-366.
39. David, J.A., Kendall, C.W.C., Ransom, T.P.P. 1998. "Dietary fiber, the evolution of the human diet and coronary heart disease." *Journal for Nutrition Research*, 18, 4, 633.
40. de Deckere, E.A.M. and Vershuren, P.M. 2000. "Functional fats and spreads." *Functional Foods*, 10, 233.
41. Department of Health, 1991. *Food for Health*. Department of Health, Wellington.
42. Dumas, J.B.A. 1831. *Ann Chim Phys*. 2(47), 198.
43. Eerlington, R.C., Deceuninck, M. and Delcour, J.A. 1993. "Enzyme-resistant starch. II Influence of amylose chain length on resistant starch formation." *Cereal Chemistry*, 70,3, 345.
44. Eiman, D., 2002. *Personal Communication*. Discussion about suitable starch slurry concentration.
45. Fabriani, C., Lintas, C. and Quaglia, G.B. 1968. "Chemistry of lipids in processing and technology of pasta products." *Journal of cereal chemistry*, 45, 5, 454.
46. Faller, J.F., Faller, J.Y. and Klein, B.P. 2000. "Physical and sensory characteristics of extruded corn/soy breakfast cereals." *Journal of Food Quality*, 23, 1, 87.
47. Fast, R.B. and Caldwell, E.F. 2000. "Breakfast cereals and how they are made." *American Association of cereal chemists*. p561
48. Faubion, J.M., Hosene, R.C., Seib, P.A. 1982. "Functionality of grain components in extrusion." *Cereal foods world*, 27, 5, 212.
49. Food Standards Australia New Zealand. 2003. "Phytosterol esters derived from vegetable oils as ingredients in fibre-increased bread and breakfast cereal bars." A433. Available:
50. Fornal, L., Soral-Śmietana, M., Śmietana, Z., Szpendowski, J. 1987. "Chemical Characteristics and Physico-chemical Properties of the Extruded Mixtures of Cereal Starches." *Starch/Stärke*, 39(3), 75.
51. Frame, N.D. Ed.1994. "The Technology of Extrusion Cooking." *Blackie academic & Professional*, Glasgow. p250
52. Fraser, G. 1994. "Diet and coronary heart disease: beyond dietary fats and low-density-lipoprotein cholesterol." *American Journal of Clinical Nutrition*, 59 (suppl), 1117s.

53. Gaosong, J. and Vasanthan, T. 2000. "Effect of extrusion cooking on the primary structure and water solubility of β -Glucans from regular and waxy barley." *Cereal Chemistry*, 77, 3, 396
54. Glore, S.R., Van Treek, D., Knehans, A.W. and Guild, M. 1994. "Soluble fibre and serum lipids: a literature review." *Journal of American Diet Association*, 94, 425.
55. Grant, C., 2000. "Communication issues facing functional foods in Europe." In Angus F. and Miller C. *Functional Foods 2000*. Leatherhead Publishing. p.352-361.
56. Gualberto, D. G., Bergman, C. J., Kazemzadeh, M. and Weber, C. W. 1997. "Effect of extrusion processing on the soluble and insoluble fiber, and phytic acid contents of cereal brans." *Plant Foods for Human Nutrition* 51, no. 3: 187-98.
57. Gutkoski, L. C., and Atia-El-Dash, A. 1999. "Effects of extrusion variables on functional and nutritional properties of extruded oat products." *Journal of Food Science and Nutrition* 4, no. 3: 159-62.
58. Guy, R. 2001. "Raw materials for extrusion cooking." In Guy, R., *Extrusion cooking: Technologies and Applications*. Woodhead Publishing Ltd., Cambridge, p5-27.
59. Guy, R.C.E. 1994. "Raw materials for extrusion cooking processes." *The Technology of Extrusion Cooking*. Blackie Academic & Professional, Glasgow, p.52-72
60. Harper, J.M., 1981. *Extrusion of Foods Volume I and II*. CRC Press, Florida.
61. Harper, J.M. and Tribelhorn, R.E., 1992. "Expansion of Native Cereal Starch Extrudates." In Kokini, J.L., Ho, C., Karwe, M.V. 1992. *Food extrusion science and technology*. Marcel Dekker Inc., New York.p.653-668.
62. Hasler, C.M. 1998. "A new look at an ancient concept." *Chemistry & Industry*, 84.
63. Hasselwander, O., Hönlein, W., Schweillert, L. and Klaus, K. 2000. "5-Methyltetrahydrofolate- the active form of folic acid." In Angus, F. and Miller C. *Functional Foods 2000*, Leatherhead Publishing, p.48-59.
64. Hayakawa, I. 1992. *Food Processing by Ultra High Pressure Twin-Screw Extrusion*. Technomic publishing Co, Lancaster, Pennsylvania. 145p.
65. Heasman, M. and Mellentin, J. 2001. *The functional foods revolution: healthypeople, healthy profits?* Earthscan, London, 313p.
66. Heasman, M. and Mellentin, J. 2002. "Strategies in functional foods and beverages." *New Nutrition Business*, 7, 3, 3.

67. Hilliam, M.A. and Young, J. 2000. "Functional food markets, innovation and prospects." Leatherhead Publishing, Surrey, 210p.
68. Hornstra G. 1999. "Lipids in functional foods in relation to the cardiovascular disease." *Paper for Nordic Lipid Symposium*, 101, 12, 456.
69. Hosoney, C.R., Mason, W.R., Lai, C.-S. and Guetzlaff, J. 1992. "Factors affecting the viscosity and structure of extrusion-cooked wheat starch." In *Kokini, J.L., Ho, C., Karwe, M.V.* (Eds) 1992. *Food extrusion science and technology*, Marcel Dekker Inc., New York. p.277-306.
70. Hsieh, F., Mulvaney, S.J., Huff, H.E., Lue, S. and Brent, J., 1989. "Effect of Dietary Fiber and Screw Speed on Some Extrusion Processing and Product Variables." *Lebensm. U.-Technol.*, 22, 204.
<http://www.new-nutrition.com/archive/37/htmldecjan02/decjan0211a.htm>.
<http://www.new-nutrition.com/newspage/060401xx.htm>
71. Hu, L., Hsieh, F. and Huff, H.E. 1993. "Corn Meal Extrusion with Emulsifier and Soybean Fiber." *Lebensm.-Wiss. u-Technol.*, 26, 544.
72. Huth, M., Dongowski, G., Gebhardt, E. and Flamme, W. 2000. "Functional properties of dietary fibre enriched extrudates from barley." *Journal of Cereal Science* 32, no. 2: 115-28.
73. James, A.S. 1999. "Key Players in the global functional foods industry." *Leatherhead international Ltd.*, Surrey, 131p.
74. Jay, M. 2000. "An industry perspective – creating a new functional foods business." In Angus F. and Miller C. *Functional Foods 2000*, Leatherhead Publishing, p38-47.
75. Jenkins, D.J.A., Kendall, C.W.C, Vuksan, V., Vidgen, E., Parker, T., Faulkner, D., Mehling, C.C., Garsetti, M., Testolin, G., Stephan, S.C., Ryan, M.A. and Corey, P.N. 1998. "Soluble fiber intake at a dose approved by the US Food and drug administration for a claim of health benefits: serum lipid risk factors for cardiovascular disease assessed in a randomised controlled crossover trial." *American Society for Clinical Nutrition*, 75, 834.
76. Johnson, I. T. 1988. Impact on nutrition. *Food Processing (Tonbridge)* 57, no. 11: 47-48, 50.
77. Kahlon, T.S., Edwards, R.H. and Chow, F.I. 1998. "Effect of extrusion on hypercholesterolemic properties of rice, oat, corn, and wheat bran diets in hamsters." *Cereal Chemistry*, 75, 6, 897.

78. Karam, L. B., M. V. E. Grossmann, and R. S. S. F. Silva. 2001. "Oat flour/waxy corn starch blends for snacks production." *Ciencia e Tecnologia De Alimentos* 21, no. 2: 158-63.
79. Kasim-Karakas, S.E. 2000. "Omega-3 Fish Oils and Insulin Resistance." In Wildman, R.E.C. *Handbook of Nutraceuticals and Functional Foods*, 1st ed., Lewis Publishers Inc., 345-352.
80. Kasim-Karakas, S.E. 2000. "Omega-3 Fish Oils and Lipoprotein metabolism." In Wildman, R.E.C. *Handbook of Nutraceuticals and Functional Foods*, 1st ed. Lewis Publishers Inc., p. 295-330.
81. Katan, M.B. 2000. "Trans fatty acids and plasma lipoproteins." *Journal of Nutrition Reviews*, 58, 6, 188.
82. Kokini, J.M, Chang, C.N. and Lai, L.S, 1992. "The role of rheological properties on extrudate expansion." In Kokini, J.L., Ho, C., Karwe, M.V. (Eds) 1992. *Food extrusion science and technology*, Marcel Dekker Inc., New York, p.631-652.
83. Kris-Etherton, P.M., Etherton, T.D., Carlson, J. and Gardner, C. 2002. "Recent discoveries in inclusive food-based approaches and dietary patterns for reduction in risk for cardiovascular disease." *Lippincott, Williams & Wilkins*. 397.
84. Krummel, D.A., Humpheries, D., Tessaro, I., 2002. "Focus Groups on Cardiovascular Health in Rural Women: Implications for Practice." *Journal of Nutrition Education and Behavior*, 34, 38.
85. Kurtzwell, P. 1998. "Staking a Claim to Good Health." U.S. Food and Drug Administration, FDA Consumer. Online. Microsoft explorer. 18/04/02. Available: <http://www.cfscan.fda.gov/~dms/fdhclm.html>
86. Kwiterovich, P.O. 1997 "The effect of dietary fat, antioxidants, and pro-oxidants on blood lipids, lipoproteins, and atherosclerosis." *Journal of the American Dietetic Association*, 97, 7, S31.
87. Labell F. 2000. "Soy protein compatible with cereals." *Journal of Prepared foods*, 169, 10, 77.
88. Labell, F. 2000. "Fish oil powder fortifies dry mixes." *Journal of R&D Applications*, 79.
89. Levy, A.S. and Fein, S.B. 1998. Consumers' ability to perform tasks using nutrition labels. *Journal of Nutrition Education*, 30, 210.

90. Levy, A.S., Derby, B.M., Roe, B.E., 1997. "Consumer impacts of health claims: An experimental study." U.S. Food and Drug Administration, Center for Food Safety and Applied Nutrition.
91. Lewis, C.J. 2000. "Letter Regarding Dietary Supplement Health Claim for Omega-3 Fatty Acids and Coronary Heart Disease." U.S. Food and Drug Administration, Center for Food Safety and Applied Nutrition. On-line. Microsoft Explorer 29/07/02. Available: <http://vm.cfsan.fda.gov/~dms/ds-ltr11.html>
92. LFRA (Leatherhead Food Research Association), 2001. "The market for heart benefit foods – a global analysis." *LFRA Limited*, 146p.
93. Li, P. X.-P.1998. "Milling and Extrusion Characteristics of New Zealand Corn. Development of a Hardness Test and On-Line Extruder Viscometer." *Thesis*. Massey University, Palmerston North, 209p.
94. Liu, Y., Hsieh, F., Heymann, H. and Huff, H. E. 2000. "Effect of process conditions on the physical and sensory properties of extruded oat-corn puff." *Journal of Food Science* 65(7): 1253-59.
95. Lund, E. K., and Johnson, I. T. 1991. "Fermentable carbohydrate reaching the colon after ingestion of oats in humans." *Journal of Nutrition*. 121, no. 3: 311-17.
96. Lund, E.K. and Johnson, I.T. 1991. "Fermentable carbohydrate reaching the colon after ingestion of oats in humans." *Journal of nutrition*, 121, 3, 311.
97. Lusas, E.W. and Rooney W. 2001. "Snack Foods Processing." Technomic Publishing Co., Lancaster, Pennsylvania, 637p.
98. Mackerras, D. 1996. "Does Vitamin E reduce the risk of heart disease?" *Proceedings of the Nutrition Society of New Zealand*, 21, 52.
99. Maga, J.A., 1989. "Flavour formation and retention during extrusion." In Mercier, C., Linko, P. and Harper, J.M. eds. *Extrusion Cooking*. American Association of Cereal Chemist, St. Paul, Minnesota.
100. Manthey, F. A., Lee, R. E. and Hall, C. A. 2002. "Processing and cooking effects on lipid content and stability of [alpha]-linolenic acid in spaghetti containing ground flaxseed." *Journal of Agricultural & Food Chemistry* 50, no. 6: 1668-71.
101. Marchioli, R., Tognoni, G. Valagussa, F. On behalf of GISSI-Prevenzione Investigators. 1999. "Dietary supplementation with n-3 polyunsaturated fatty acids and vitamin E after myocardial infarction: Results of the GISSI-Prevenzione trial." *Lancet*, 354, 447.

102. Marconi, E., Graziano, M., Cubadda, R., 2000. "Composition and Utilization of Barley Products for Making Functional Pastas Rich in Dietary Fiber and β -Glucans." *Cereal Chemistry*, 77(2), 133.
103. Marsman, G.J.P, Gruppen, H., Zuillichem, D.J., Resink, J.W. and Voragen, A.G.J. 1995. "The influence of screw configuration on the in vitro digestibility and protein solubility of soybean and rapeseed meals." *Journal of Food Engineering*, 26, 1, 13.
104. Matheson, D. 2002. "Food and nutrition guidelines for healthy adults: a background paper." Ministry of Health, Wellington, 114p. Available: <http://www.moh.govt.nz>
105. McColl, L., Marketing Manager, Nice and Natural Ltd. 2003. Personal Communication, re. *Market share of Uncle Tobys breakfast cereals and comparative estimated market share for Nice and Natural products.*
106. McIntosh, G.H., Newman, R.K. and Newman, C.W. 1995. "Barley Foods and their Influence on Cholesterol Metabolism." *Plants in Human nutrition*, 77, 89.
107. Megazyme, 2001. "Total Dietary Fibre Assay Procedure." Megazyme International Ireland Ltd. Available: <http://www.megazyme.com/booklets/KTDFR.pdf>.
108. Megazyme, 1998. "Assay of Mixed Linkage Beta-Glucan in Oat and Barley Flour and Fibre Samples – Streamline Method." Megazyme International Ireland Ltd. Available: <http://www.megazyme.com/booklets/KBGLU.pdf>.
109. Mellentin, J. 2002. "&More turns out to be less." *New Nutrition Business*, 8, 2.
110. Meydani, M. 2000. "Effect of functional food ingredients: vitamin E modulation of cardiovascular diseases and immune status in the elderly." *American Society of Clinical Nutrition*, 1665.
111. Mitchell and Areas, 1992.
112. Morrissey, P.A and O'Brien, N.M. 1998. "Dietary Antioxidants and Health Disease." *International Dairy Journal*, 8, 463
113. Murray, J.M. 2001. "Descriptive sensory analysis of a maize based extruded snack." *Food Australia* 53(1,2), 24.
114. Narpinder S., and Smith, A. C. 1997. "A comparison of wheat starch, whole wheat meal and oat flour in the extrusion cooking process." *Journal of Food Engineering* 34, no. 1: 15-32.
115. Nawar, W. W. 1996 "Lipids." In Fennema, O.R. Ed. *Food Chemistry*. 3rd Edition, Marcel Dekker Inc., New York. p. 225-320.

116. Nguyen, T.T. 1999. "The Cholesterol-lowering action of Plant Stanol esters." *American Society of nutritional Sciences*, 2109.
117. NZHIS (New Zealand Health Information Service), 2003. "Mortality and Demographic Data 1999." Ministry of Health, Wellington, 160p. Available: www.nzhis.govt.nz/publications/Mortality.html
118. O'Connor, C., Ed. 1987. *Extrusion Technology for the Food Industry*. Elsevier Applied Science Publishers Ltd, Essex.
119. Oniang'o, R.K. 1998. "Fibre: implications for the consumer." *Nutrition research*, 18, 661.
120. Onwulata, C.I., Konstance, R.P., Strange, E.D., Smith, P.W. and Holsinger, V.H. 2000. "High-fiber snacks extruded from triticale and wheat formulations." *Cereal foods world*, 45, 10, 470.
121. Oomah, B. D., Kenaschuk, E. O., and Mazza, G. 1997. "Tocopherols in flaxseed." *Journal of Agricultural & Food Chemistry* 45, no. 6: 2076-80.
122. Parker, J.K., Hassell, G.M.E, Mottram, D.S. and Guy, R.C.E. 2000. "Sensory and instrumental analyses of volatiles generated during extrusion cooking of oat flours." *Journal of Agricultural and Food Chemistry*, 48, 8, 3497.
123. Patterson, D., Zappelli, R., Chalmers, A., 2001. "Food Labelling Issues – Consumer Qualitative Research." NFO Donovan Research, 102p. Available: <http://www.foodstandards.gov.au/mediareleasespublications/publications/foodlabelingissuesconsumerresearchdecember2001/index.cfm>
124. Plous, S., Chesne, R.B., McDowell, A.V. 1995. "Nutrition knowledge and attitudes of cardiac patients." *Journal of the American Dietetic Association*. 95(4), 442.
125. Ralet, M.-C., Thibault, J.-F. and Della Valle, G., 1991. "Solubilization of Sugar-beet Pulp Cell Wall Polysaccharides by Extrusion-cooking." *Lebensm.-Wiss. u.-Technol.*, 24, 107.
126. Rao, S.K. and Artz, W.E. 1989. "Effect of Extrusion on Lipid Oxidation." *Journal of food science*, 54, 6, 1580
127. Riaz, M.N. Ed. 2000. *Extruders in food applications*. Technomic Publishing Co., Lancaster, Pennsylvania p.127-147.
128. Riaz, M.N., 2001. "Selecting the right Extruder." In Guy, R., *Extrusion cooking: Technologies and Applications*. Woodhead Publishing Ltd., Cambridge, p29-49.

129. Rimm, E.B., Asherio, A., Giovannucci, E., Spiegelman, D., Stampfer, M.J. and Willett, W.C. 1996. "Vegetable, fruit and cereal fibre intake and the risk of coronary disease among men." *The Journal of American Medical Association*, 275, 446.
130. Ripsin, C.M., Keenan, J.M., Jacobs, D.R., Elmer, P.J., Welch, R.R., Van Horn, L., Liu, K., Turnbull, W.H., Thye, W., Kestin, M., Hegsted, M., Davidson, M.H., Dugan, L.D, Dehmark-Wahnefried, W., Beling, S. 1992. "Oat products and lipid lowering – a meta analysis." *J. Am. Med. Assoc.*, 267, 3317.
131. Roberts, D. 1999 "Carbohydrates and Dietary Fibre." *The National Heart Foundation of New Zealand*, Auckland, 25p.
132. Roberts, D. 2002, Personal Communication. Discussion regarding promotion of nutrients vs wholefoods.
133. Roche, H.M. 1999. "Unsaturated fatty acids." *Proceedings of the Nutrition society*, 58, 397.
134. Rowland, I. 1999. "Optimal Nutrition: Fibre and phytochemicals." *Proceedings of the nutrition society*, 58, 415.
135. Ruales, J., Polit, P. and Nai, B.M. 1988. "Nutritional quality of blended foods of rice, soy and lupins, processed by extrusion." *Journal of food chemistry*, 29, 4, 309.
136. Rudra, P.K., Nair, S.S.D., Leitch, J.W. and Garg, M.L. 2001. "Omega-3 Polyunsaturated fatty acids and cardiac arrhythmias." In Wildman, R.E.C. *Handbook of Nutraceuticals and Functional Foods*, Lewis Publishers Inc. 1st ed. p331-344.
137. Russell, D., Parnell, W., Wilson, N. 1999. "NZ Food:NZ People, Key Results of the 1997 National Nutrition Survey." Ministry of Health, Wellington. 280p. Available:
[http://www.moh.govt.nz/moh.nsf/ea6005dc347e7bd44c2566a40079ae6f/8fldbebl1e0e1c70c4c2567d80009b770/\\$FILE/nns.pdf](http://www.moh.govt.nz/moh.nsf/ea6005dc347e7bd44c2566a40079ae6f/8fldbebl1e0e1c70c4c2567d80009b770/$FILE/nns.pdf)
138. Sadler, M.J. and Saltmarsh, M. Eds. 1998. *Functional Foods: the consumer, the products and the evidence*. Royal Society of Chemistry, Cambridge, 215p.
139. Schaefer, E.J. 2002. "Lipoproteins, nutrition and heart disease." *American Society for Clinical Nutrition*, 75, 191.
140. Schlude, M., 1987. "The Stability of Vitamins in Extrusion Cooking." In O'Connor, C., Editor. *Extrusion Technology for the Food Industry*. Elsevier Applied Science Publishers Ltd, Essex.

141. Schmidt, D.B., Morrow, M.M. and White, C. 1998. "Communicating the Benefits of Functional Foods: Insights from Consumer and Health Professional Focus Groups." *American Chemical Society*, 2,10.
142. Seddon, M. 1999. "Soy and Soy-based foods." *The National Heart Foundation of New Zealand*, Auckland, 10p.
143. Semwal A.D, Sharma, G.K. and Arya, S.S. 1994. "Factors influencing lipid autoxidation in dehydrated pre-cooked rice and Bengalgram dhal. *Journal of Food Science and Technology*, 31 (4):293-297.
144. Shepherd, J. 1998. "International comparison of awareness and attitudes towards coronary risk factor reduction: the HELP study. Heart European Leaders Panel." *Atherosclerosis*. 137 Suppl, S117.
145. Shinnick, F.L., Longacre, M.J., Ink, S.L and Marlett, J.A. 1988. "Oat fiber: composition versus physiological function in rats." *American institute of nutrition*, 144.
146. Shortt, C. 2000. "Yakult: From research to market." In Angus F. and Miller C. *Functional Foods 2000*. Leatherhead Publishing. p.165-172.
147. Siljestrom, M., Westerlund, E., Bjoerck, I., Holm, J., Asp, N. G., Theander, O. 1986. "The effects of various thermal processes on dietary fibre and starch content of whole grain wheat and white flour." *Journal of Cereal Science*, 4, (4):315-323.
148. Simopoulos, A.P, Leaf, S. and Salem, N. 1999 "Workshop on the Essentiality of and recommended dietary intakes for Omega-6 and Omega-3 Fatty acids." Online. Microsoft explorer 17/09/02. Available: www.issfal.org.uk/adequateintakes.htm
149. Simopoulos, A.P. 1991. "Omega-3 fatty acids in health and disease and growth and development." *American society for clinical nutrition*, 54, 438.
150. Simopoulos, A.P. 1999. "Essential fatty acids in health and chronic diseases." *American Journal of Clinical Nutrition*, 70, 3, 560.
151. Sinclair, A.J. 1993. "The nutritional significance of Omega 3 polyunsaturated fatty acids for humans." *Asean food Journal*, 8, 1, 3.
152. Singh, N. and Smith, A.C. 1997. "A comparison of wheat starch, whole wheat meal and oat flour in the extrusion cooking process." *Journal of food engineering*, 34, 15.
153. Slavin, J. 1991 "Nutritional benefits of soy protein and soy fibre." *Journal of the American Dietetic Association*. 91, 816

154. Slavin, J. L., D. Jacobs, and L. Marquart. 2000. Grain Processing and Nutrition. *CRC Critical Reviews in Food Science & Nutrition*, 40(4), 309.
155. Sloan, A.E. 2000. "The top ten functional foods trends." *Journal of Food technology*, 54, 4, 33.
156. Strain, J.J and Benzie, I.F.F "Antioxidant Nutrients." In Sadler, M.J. and Saltmarsh, M. Eds. 1998. *Functional Foods: the consumer, the products and the evidence*. Royal Society of Chemistry, Cambridge, 215p.
157. Suknark, K., J. Lee, R. R. Eitenmiller, and R. D. Phillips . 2001. Stability of tocopherols and retinyl palmitate in snack extrudates. *Journal of Food Science* 66, no. 6: 897-902.
158. Suzuki, H., Chung, B.S, Isobe, S., Hayakawa, S.and Wada, S. 1988 "Changes in omega-3 polyunsaturated fatty acids in the chum salmon muscle during spawning migration and extrusion cooking." *Journal of Food Science*, 53, 6, 1659.
159. Tahvonen, R., A. Hietanen, T. Sankelo, V. M. Kortenieniemi, P. Laakso, and H. Kallio. 1998. "Black currant seeds as a nutrient source in breakfast cereals produced by extrusion cooking." *Zeitschrift Fur Lebensmittel-Untersuchung Und-Forschung A-Food Research & Technology* 206, no. 5: 360-363.
160. Theander, O. and Westerlund, E. 1987. "Studies on Chemical Modifications in Heat-processed Starch and Wheat Flour." *Starch/Stärke*, 39(3), 88.
161. Thompson, D. B., and J. W. J. r. Erdman. 1981. Nutrient bioavailability. *Acs Symposium Series* 147243-274.
162. Tietyen, J. L. 1994. Production and nutritional evaluation of an extruded snack containing soy fiber and plant protein. *Dissertation* 54, no. 12.
163. Truswell, A.S. 2002. "Review. Cereal grains and coronary heart disease." *European journal of clinical nutrition*, 56, 1.
164. U.S. Food and Drug Administration (USFDA), 2000. "A Food Labeling Guide— Appendix C, Health Claims." U.S. Food and Drug Administration, Center for Food Safety and Applied Nutrition. Online. Microsoft Explorer 6/10/03 Available: <http://www.cfsan.fda.gov/~dms/flg-6c.html>
165. Unlu, E. and Faller, J.F. 1998. "Formation of resistant starch by a twin-screw extruder." *Cereal Chemistry*, 75, 3, 346.
166. Von Schacky C. 2000. "n-3 fatty acids and the prevention of coronary atherosclerosis." *American Journal of Clinical Nutrition*, 71, 1, 224.

167. Wallingford, J.C. and Yetley, E.A. 1991. "Development of the health claims regulations: the case of omega-3 fatty acids and heart disease." *Journal of Nutrition Reviews*, 49, 11, 323.
168. Wander, R.C. 2001. "Lipid Oxidation in Biological Systems Enriched with long chain-3 fatty acids." *Handbook of nutraceuticals and functional foods*, 305.
169. Wang Changqing, and Zhu Zhiang. 2002. Study on the extruding production method of soluble oats fiber. *Food and Fermentation Industries* 28, no. 2: 45-48.
170. Wang, W. M., and C. F. Klopfenstein. 1993. Effect of twin-screw extrusion on the nutritional quality of wheat, barley, and oats. *Cereal Chemistry* 70(6), 712.
171. Welch R.W. 1998. "Oats – a multifunctional food." In Sadler and Saltmarsh, Eds. 1998. *Functional Foods: the consumer, the products and the evidence*. Royal Society of Chemistry, Cambridge, p99-105.
172. White, H. (Ed.) 1999. "Nutrition and Cardiovascular Disease: An Evidence Summary." *The National Heart Foundation of New Zealand*, 77. 18p.
173. Whyte, J.L., McArthur, R., Topping, D. and Nestel, P. 1992. "Oat bran lowers plasma cholesterol levels in mildly hypercholesterolemic men." *American Dietetic association*, 92, 4,446.
174. Wicklund, T., and E. M. Magnus. 1997. Effect of extrusion cooking on extractable lipids and fatty acid composition in sifted oat flour. *Cereal Chemistry* 74, no. 3: 326-29.
175. Wilcox, S. and Stefanick, M.L. 1999. "Knowledge and perceived risk of major diseases in middle-aged and older women." *Health psychology*, 18, 4, 346.
176. Williams, P. 1998. "Health Claims and Functional Foods: Time for a regulatory change." *Australian Journal of Nutrition & Dietetics*, 55(2), 87.
177. Winger, R.J., Taylor, M., Singh, H., Duizer, L.M., Glasgow, S. and Ha, M. 1999. "141.391 Food Chemistry Laboratory Manual." Massey University, Palmerston North, 68p.
178. Winkler, J.T. 1998. "Consumer Issues and Functional Foods." In Sadler, M.J. and Saltmarsh, M. Eds. *Functional Foods: the consumer, the products and the evidence*. Royal Society of Chemistry, Cambridge. p. 84-195.
179. Wiseman, H., O'Reilly, J.D., Lim,P., Garnett, A.P., Huang W.-C. and Sanders, T.A.B., 1998. "Antioxidant Properties of the isoflavone-phytoestrogen functional ingredients in soya products." In Sadler, M.J. and Saltmarsh, M. Eds. *Functional*

- Foods: the consumer, the products and the evidence*. Royal Society of Chemistry, Cambridge, p.80-85.
180. Wiseman, J. 1994. "Beliefs about food components, foods fat and heart disease in New Zealand." *British food Journal*, 96, 11, 101.
181. Wiseman, J. 1995 "Knowledge, Attitudes, Beliefs On Food and Heart Disease. *Report for the National Heart Foundation*.67p.
182. Wood P.J. and Beer M.U 1998. "Functional Oat Products." In Mazza, G. *Functional Foods: biochemical and processing aspects*. Technomic Publishers, Lancaster, p. 1-37.
183. Woods, M.P, 1994. "The Role of Marketing Communication in the Introduction of Functional Foods to the Consumer" In Goldberg, I. (Ed.) *Functional Foods: Designer Foods, Functional Foods, Nutraceuticals*. Chapman & Hall, New York, p.495-511.
184. Worsely, A. 2000. "Food and consumers: Where are we heading?" *Asia Pacific J Clin Nutr*, 9 (Suppl), S103.
185. Worsely, A. and Scott, V. 2000. "Consumers' concerns about food and health in Australia and New Zealand." *Asia Pacific J Clin Nutr*, 9(1)24.
186. Worsley, A. 2002 "Nutrition knowledge and food consumption: can nutrition knowledge change food behaviour?" *Asia Pacific J Clin Nutr*, 11, S579.
187. Wrick, K.L. 1995. "Consumer Issues and Expectations for Functional Foods." *Critical Reviews in Food Science and Nutrition*. 35(1&2), 67.
188. Yetley, E.A.1999. "re: Petition for Health Claim: Folic Acid, Vitamin B6, and Vitamin B12 Dietary Supplements and Vascular Disease (Docket Number 99P-3029). Food and Drug Administration, Center for Food Safety and Applied Nutrition, Washington, 16p.
189. Young, J. 1998. "Consumer Issues and Functional Foods." In Sadler, M.J. and Saltmarsh, M. Eds. *Functional Foods: the consumer, the products and the evidence*. Royal Society of Chemistry, Cambridge.
190. Zadernowski, R., H. Nowak-Polakowska, T. Wicklund, and L. Fornal. 1997. Changes in oat lipids affected by extrusion. *Nahrung*, 41, 4, 224-27.
191. Zammer, C. 2000. "Strategic options for succeeding in functional foods: filling the gap between reality and ambition." In Angus, F. and Miller, C. *Functional Foods 2000*. Leatherhead publishing. P.422-429.

192. Zielinski, H., E. Ciska, and H. Kozłowska. 2001. The cereal grains: focus on vitamin E. *Czech Journal of Food Sciences* 19, no. 5: 182-88.
193. Zielinski, H., H. Kozłowska, and B. Lewczuk. 2001. Bioactive compounds in the cereal grains before and after hydrothermal processing. *Innovative Food Science & Emerging Technologies* 2, no. 3: 159-69.

11. APPENDIX OUTLINE

The appendix is presented in a digital form. The appendix is available on the CD-Rom attached inside the back cover of this thesis. Each section may be found in a folder labelled with a name corresponding to the title described in the outline below.

APPENDIX A: CONSUMER RESEARCH METHODS

A1: HUMAN ETHICS APPROVAL

A2: LETTER TO ORGANISER TO RECRUIT FOCUS GROUP PARTICIPANTS

A3: INFORMATION SHEET FOR FOCUS GROUP PARTICIPANTS

A4: FOCUS GROUP PARTICIPANT CONSENT FORM

A5: CONSUMER SURVEY

A6: OUTLINE OF THE FOCUS GROUP DISCUSSION TOPICS

A7: PROMPTS FOR DESIRED NUTRIENTS AND PROPERTIES TO INCLUDE IN A HEART HEALTH BAR

APPENDIX B: CONSUMER SURVEY RESULTS

B1: Consumer Demographics

B2: Heart Health Concern and Food Choices

B3: Heart Health Benefit Association

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B3.2 Oats and Beta-Glucan

B3.3 Psyllium

B3.4 Fat

B3.5 Omega-3

B3.6 Plant Sterols

B3.7 Soy

B3.8 Folate

B3.9 Antioxidants

B3.10 Sodium

APPENDIX C: SCREENING

C1: Development of Screening Factors

C2: Cost Analysis

C3: Individual Screening Scores

APPENDIX D: RAW MATERIAL SPECIFICATIONS

D1: RMS Oat Flour (Harraways)

D2: RMS Oat Bran (Harraways)

D3: RMS Thermflo Starch (National Starch and Chemical)

D4: RMS Hylon VII Starch (National Starch and Chemical)

D5: RMS Avon Starch (Penfords New Zealand)

D6: RMS Promozyme 400L, pullanase enzyme (Novo Nordisk A/S)

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