CONSUMER MARKET RESEARCH FOR OPTIMIZATION OF AN EXTRUDED SNACK PRODUCT AND PROCESS FOR THE INDONESIAN MARKET

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ABSTRACT

A coextruded snack based on corn, defatted soya flour and Indonesian ingredients (rice and/or tapioca) was developed for Indonesian consumers, particularly to fit into the young adult niche market. Market and consumer research was carried out through collecting primary and secondary data and the results were utilized in the formulation of the extruded snack. Information about the snack market situation in Indonesia and consumer attitude towards extruded snack products indicated that there is an opportunity for success for a new-western style snack (extruded snack) in Indonesia and the key for success are product awareness and product attributes, notably crispiness and flavour.

The snack base was manufactured using a co-rotating and intermeshing twin screw extruder (Clextral BC-21) with a constant feed rate and optimized by changing ingredients and extrusion conditions set by a constrained mixture design scheme (Echip computer software). The effect of the extrusion conditions and ingredients on the functional, physical properties of the snack product was also studied in this project. The product cost was also optimized with a constraint of no more than Rp. 4000 per kg (NZ$ 2.70) finish snack product.

The study on the extrudate properties showed that an increase in rice flour increased moisture content (MC), Water Absorption Index (WAI), Nitrogen Solubility Index (NSI) and Breaking Strength (BS), while an increase in soya reduced the protein solubility and the extrudate became brownish. Consumer acceptability was mainly affected by the rice content, soya content and temperature in the last section (T4).

Specific Mechanical Energy (SME), an extrusion parameter, was calculated directly through torque measurements. Higher SME indicated higher energy used in the extrusion process, thus more starch degradation and protein denaturation occurred, producing extrudates with lower BS. Sensory evaluation showed that snacks with lower BS (a crispier product), higher L^* and b^* colour (light brownish yellow colour) had a higher acceptance.

The most preferred snack base was made from 28% defatted soya flour, 12% rice flour, 59.6% corn grits and 0.4% baking soda. These ingredients were processed in a twin screw extruder with a feed rate of 4.47 kg/hr. The four barrel temperature zones were set at 40°C, 80°C, 115°C and 140°C, respectively and 150 ml/hr of water was pumped to the barrel. The screw speed was set at 300 rpm. The snack acceptance was improved by coating the samples with flavours and the most preferred flavour determined by a sensory panel was a spicy flavour (Ethican - QZ 02346; Quest International).

The optimum product formulation was then tested in a larger scale consumer test in Indonesia. The results from the final product testing showed that the developed snack was accepted by the target consumers. However some improvements of the product in terms of oil content and product stickiness in the mouth are still necessary. The developed product had a better acceptance over the snacks already in the market in terms of nutritional image, crispiness, product appearance and main ingredients.

In addition a feasibility study on snack production in a single screw extruder was carried out and functional and physical properties of the resulting extrudates were compared with those produced using the twin screw extruder. The comparison of WAI, Glass transition temperature (Tg), NSI and BS of snacks manufactured using a single (Lalesse, Universal single screw extruder) and a twin screw extruder (Clextral BC21) showed that the extent of molecules degradation was lower in the single screw extruder than in the twin screw extruder. Sensory properties also indicated that the twin screw extrudate was crispier and suited to the consumers' preference than the single screw extrudate.

The developed product could be produced commercially either using a twin screw extruder or a single screw extruder, depending on the available equipment, although it was recognized that the snack manufactured using the twin screw extruder had a higher preference compared to those produced using the single screw extruder.

DEDICATION

to my parent, Mr. and Mrs. Harminto,
my sister and brothers, Daili, Ibnu and Ardian
for their understanding and encouragement throughout my course.

Make the best use of your possessions and capabilities to gain your goal;
and accept the limits of the situation.
It is THE WAY IT IS, therefore LET IT GO.

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SYMBOLES AND ABBREVIATIONS

TSE	:	Twin Screw Extruder
SSE	:	Single Screw Extruder
RSE	:	Reverse Screw Element
T1	:	Temperature at the first zone in the twin screw extruder
T2	:	Temperature at the second zone in the twin screw extruder
T3	:	Temperature at the third zone in the twin screw extruder
T4	:	Temperature at the forth/last zone in the twin screw extruder
MC	:	Moisture Content
w/w	:	Weight per weight basis
wwb	:	Weight by wet basis
WAI	:	Water Absorption Index
WSI	:	Water Solubility Index
NSI	:	Nitrogen Solubility Index
Tg	:	Glass transition temperature
BS	:	Breaking Strength
SME	:	Specific Mechanical Energy

All other abbreviations are standard chemical, mathematical or country symbols.

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INTRODUCTION

1.1 PRODUCT DEVELOPMENT

Product development is an applied industrial research system to develop new products or to improve the products at present manufactured (Mac Nulty, 1989; Earle, 1994). The role of product development for the industry includes creating new products for a new market, entering to an established market, adding new products to existing product lines, improving product existing products and reducing costs (Anderson, 1994). The product development process involves the application of different techniques, such as consumer research, process development, product formulation, engineering and marketing to develop new products or to improve the existing products already in the market.

The characteristics of a developed product depend on several factors, such as target consumer demands, company policy and strategy, availability of technology, introduction of new raw materials, government statutory requirements and competitors (Wilbey, 1990). Consumer demands change with time and the products need to be improved to meet these demands. The company may want to reduce the formulation cost, to introduce new raw materials or processing technologies, or to maintain the market share. Anderson (1994) noted that industrial companies could reach their growth goals much more quickly through new products, rather than through the increase on sales of existing products. In addition, changes in government statutory requirements could cause an industry to re-formulate an existing product.

The product development process consists of several steps (Earle, 1994; Les Bratt, 1988). The main steps of a systematic product development process described by Earle (1994) are shown in Table 1.1.

Table 1.1 Systematic product development process

-	Development of project aim and objectives
-	Setting the project constraints
-	Product idea generation
-	Searching technical and market information search
-	Product idea screening
-	Detailed study of the market, product and process feasibility
-	Development of the product concept and product specification
-	Development of the prototype product
-	Development of a suitable manufacturing method
-	Testing of the product
-	Development of a market plan and organising type of product launching
-	Evaluation of the probable product success
-	Launching the product

This project did not, however, involve the whole process as described in table 1.1. The work was focused on the development of prototype product through product optimization.

1.2 CONSUMER INVOLVEMENT IN THE PRODUCT DEVELOPMENT PROCESS

Consumers can provide useful information to be used during the product development process. Traditionally, in food product development, there are three major stages at which the consumer input can be incorporated: initial market and consumer research, sensory testing and final market test (Lai, 1987; Uaphithak, 1994).

In the early stages of product development, product developers need some guidance on how to develop the product to gain consumers' acceptance. Attributes that play an important role in consumers' acceptance and buying intentions have to be identified (Uaphithak, 1994). Les Bratt (1988) noted that consumers, in fact, do not really need anything new at all, but they are interested in improved properties or values on existing products which make the products more appeal to purchase or to use. For this reason, consumers' concern about the product improvement should be taken into account in the development. Several techniques have been used to draw out information about the important attributes from consumers (Moskowitz & Chandler, 1978; Heeler *et al.*, 1979). For example consumer survey and focus group were used in the development of bakery snacks for Malaysian market (Lai, 1987).

Using important attributes identified by consumers, the product developer can develops an optimum product formulation. As the product is targeted to fulfil the consumer satisfaction, it is logical that consumers be involved in the sensory testing to obtain an optimum formulation. A product which is accepted by target consumers has a higher chance of success in the market. After an optimum formulation is obtained, the formulation is normally scaled-up for large production. Changes in product characteristics could occur during this scale-up. Therefore a sensory testing involving consumers is also required at this stage.

Final consumer testing is normally conducted to reduce the risk of product failure. The testing includes to evaluate product acceptance, such as overall acceptability, purchase intention and price to buy. In the final product testing, developers may wish to compare the new product with the market leader or a current formula. By comparison of the developed product with commercial products, it is possible to identify unique advertising points of view about the product. Marketing information, such as price, brand name and packaging can be included in product testing. Product acceptance and purchase intention is normally evaluated at this stage (Uaphithak, 1994). Even though consumer purchase intention is influenced by factors other than the product itself, product optimization is still necessary, because if a product contains the attributes which satisfy consumers' needs, it will have more chance of competing successfully with other products on the market.

Overall, consumers are obviously important in the development process and their concerns should be taken into account during the product development. Table 1.2 shows the number of panellists that could be involved in the different stages of a product development process (Anderson, 1981).

Table 1.2 Consumer panel involvement in the product development process

Stages of product development	Number of panellists	
Product idea generation	6 - 8 consumers	
Product idea screening	6 - 8 consumers	Increasing importance of drawing right conclusions and making right decisions
Product formulation		
Initial testing		Increasing penalty for wrong decisions
Later testing	6 - 8 consumers 10 - 15 consumers	
Pilot plant trials		Increase in panel size
Initial testing		
Later testing	10 - 15 consumers 30 - 50 consumers	
Production trials		
testing	50 - 100 consumers	
Market trials		
Consumer testing or market test	200-300 consumers (representative of market segment)	
Final product release	central location test	

Source: Anderson (1981)

1.3 WHY AN EXTRUDED SNACK WAS SELECTED AS THE PROTOTYPE PRODUCT FOR THE INDONESIAN MARKET

Extrusion technology for snacks manufacture has developed rapidly. An extruder is one of the most cost effective pieces of equipment for adding value to simple raw materials, such as corn. Low value materials such as corn grits can produce highly acceptable snacks after being processed by an extruder. Developing a product using the extrusion process improves the value of lower cost raw materials.

In the extrusion process the properties of the produced snack are affected by the interaction between raw materials and the extruder operating conditions. In addition, different extruders may also provide different process conditions, thus producing products with different characteristics. The interactions between raw materials and the extruder processing conditions are not easy to describe and a great deal of research is needed to provide a better understanding about how these interactions affect the product characteristics.

In the Indonesian snack market, extruded snacks are relatively new and the different types of extruded snacks are still limited. The lack of extruded snack products may offer a possibility of developing new coextruded snacks using NZ and local Indonesian raw materials which are acceptable to the Indonesian consumers.

Exporting of food is one of the major sources of income in NZ. Besides dairy and meat products, NZ has potential for unique agricultural crops. Corn is a classic example which has been utilised for many food products, such as canned sweet corn, corn extruded snacks and corn chips. The development of an extruded product using NZ and Indonesian raw materials may extend the bilateral trade relationship between NZ and Indonesia.

1.4 AIM AND OBJECTIVES

The aim of this work was to investigate the feasibility of coextrusion of NZ produced corn grits with defatted soya flour and other Indonesian products (eg. tapioca, rice) to produce an acceptable snack for the Indonesian market, using twin and single screw extruders.

Specific objectives were to:

- conduct a market research and a consumer study for snack products in Indonesia;
- characterise the functional properties of the main ingredients used in the product formulation and their effect on the physical, functional and sensory characteristics of the extruded snack product;
- use linear programming to optimize the cost of a range of formulations appropriate for the extrusion process;
- develop a product acceptable to the Indonesian market using experimental design techniques;
- test the developed product in the target market which involves sensory evaluation of the product and consumer research;
- compare the extruded snack characteristics manufactured by twin and single screw extruders.

1.5 PROJECT CONSTRAINTS

The product optimization process was carried out with the following constraints.

Product constraints

- The product must be made from NZ produced corn grits combined with Indonesian raw materials.
- The product must be an extruded snack type product.
- The product taste must be accepted by Indonesian consumers.

Processing constraints

- The product must be produced using an available extrusion equipment and process technology.

Marketing constraints

- The product should be marketed in Indonesia as a snack product.
- The price should be comparable with similar products in the Indonesian market (less than Rp.4000 (Indonesian rupiah) or about NZ $2.7).
- The product should fit into the Indonesian market niche.

1.6 PROJECT STRATEGY

To obtain the developed product which fulfils the aim of the project and complies the constraints, the research was set using the strategy shown in Figure 1.1.

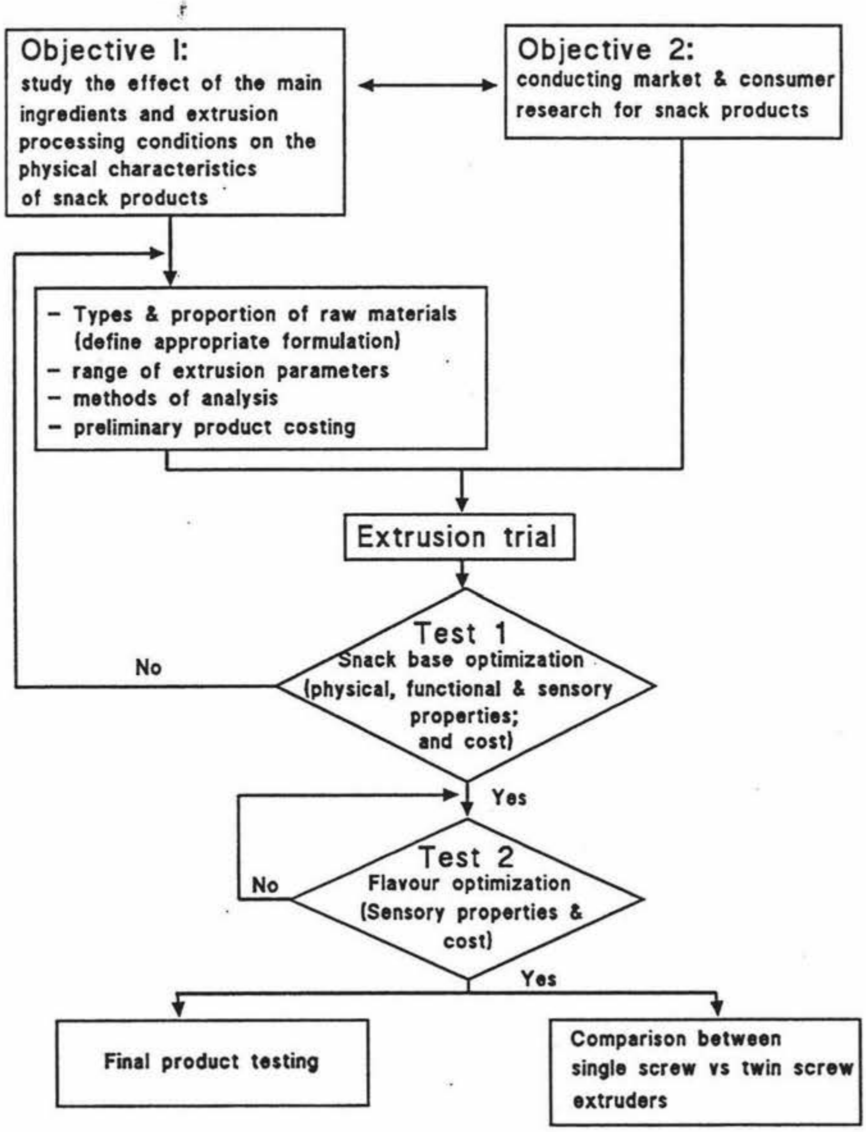

Figure 1.1 Schematic diagram of the project strategy

LITERATURE REVIEW

2.1 EXTRUSION

2.1.1 Definition

Several terms, i.e. *extrusion, extruder, extrudate, extruded snack and expanded snack* are frequently used in this manuscript. In order to avoid confusion, a definition of each will be provided.

Extrusion is a transformation process from a granular raw material into a continuous mass by forcing the material along the barrel and through a die. This process is obtained under high temperatures and short times (HTST) conditions, combined with elevated shear and pressure. The equipment used for this cooking process is known as an ***extruder***, while the product obtained is identified as the ***extrudate***. The extrudate, in this study, is the snack which is expanded directly after passing through the die, therefore terms as ***expanded snack*** or ***extruded snack*** will be used to refer to the extrudate.

According to Jowitt (1984), extrusion is a simple thermomechanical operation. which is affected by a number of variables. These variables include the extruder design, the composition of ingredients and the operating conditions. The extruder design controls the function, efficiency and capability of the extruder (Harper, 1986). While the composition of the ingredients being extruded has a significant effect on the characteristic of the extrudate (El-Dash *et al.*, 1984). Operating conditions, particularly the extruder temperature, raw materials moisture content and cooking time (residence time) also have a large effect on the product characteristics (Conway, 1971[a], 1971[b]). Preconditioning the feed before extrusion and the addition of additives can also affect the properties of the final product.

Overall, there are many variables which interact each other during the cooking process. The type of extruder influences the process and the flexibility in using a range of raw materials. The process conditions can be adjusted to process a large range of raw materials. The characteristics of the finished product are the result of the complex contribution of the base ingredients, process conditions and extruder used. An understanding of the effects of each variable and their interactions during the extrusion process would assist to the development of new extruded products.

2.1.2 Extruder design

A food extruder has several functions which includes gelatinization/cooking, molecular shearing, mixing, sterilization, forming and puffing/drying (Rossen & Miller, 1973; Huber & Rokey, 1990). The ability to run these functions varies among extruders and operation conditions. Depending on functionality, Harper (1986) divides extruders into three parts: preconditioner, screw and die; while depending on mechanical design, they can be classified as being either single or twin screw extruders.

The preconditioner is either an atmospheric or a pressurized chamber in which raw granular food ingredients are uniformly moistened and/or heated by contact with live steam or water (Harper, 1986). One of the most important feature of the preconditioner is that it can deliver uniformly pretreated ingredients to the feed section of the extruder consistently. This uniform feed gives an even distribution of materials which improves the extrusion operation.

Moore (1994) stated that a preconditioner is required to control the feed moisture in the snack manufacture using single screw extruder. The need for a preconditioner can be eliminated when a twin screw extruder is used. The water can be metered directly into the extruder barrel and the twin screw design will provide enough mixing to distribute the water. However, it has been recognized that depending on the product, preconditioning can improve the efficiency of the twin screw extrusion process as well as the quality of the final product (Jones, 1995, personal communication).

The extruder screws are, perhaps, the most important parts of the extruder, since the major molecular transformation occurs in this section, as the ingredients pass through the barrel (Harper, 1986). During the extrusion process the ingredient mixture temperature increases in the barrel. This increase in temperature is obtained through three mechanisms. First, when the screw turns, mechanical dissipation energy occurs, as the result of the material friction. This friction heats the raw ingredients. The second mechanism is when heat is transferred through the barrel jackets (external heating). The third mechanism is heating through steam injection. Most of this heat is used to plasticize the materials. This plasticized material is conveyed along the barrel by the screw and is then forced through a die.

A die is a plate placed at the end of the barrel. It has one or more shaped holes through which the material passes when leaving the extruder. The die shape influences the product shape and texture, but it may not relate to the type of extruder used to form the dough (Harper, 1986). Shear rates at the die are very high and has a large effect on the product texture. High shear rates at the die cause shear-induced damage reducing molecular size of the compounds forming the product, creating softer-textured products with smaller air cells, increased solubility and less mechanical strength.

According to Moore (1994), in the case of direct expanded snack food, the plasticized mass reaches a temperature over 100°C prior to its exit through the extruder die. At this point, the pressure of the mass is greater than the water vapour pressure. As the material exits the die, the pressure drops across the die causing the water to flash off as steam. This sudden evaporation of the water results in an expansion of the plasticized materials and gives the extruded product its characteristic internal structure and external form. The extrudate moisture content can drop to 8-12%.

2.1.2.1 *Single screw extruder*

The single screw extruders are widely used in extrusion cooking of foods. In general, single screw extruders can be divided into 4 groups: low shear forming, low shear cooking, medium shear cooking and high shear cooking (Hauck, 1985; Huber & Rokey, 1990). Low shear extruders have a grooved barrel to facilitate mixing. High shear cooking is usually identified as a HTST cooking extruder, as it works at a relatively high temperature and very short residence time (Rossen & Miller, 1973; Smith, 1974). Although low shear extruders could manufacture snack products, the high shear cooking extruder is more extensively used for the production of snack and dry pet foods.

Snack products are mostly manufactured using single screw extruders. Three types of single screw extruders are commonly used: collet extruder, fried collet extruder and cooking & forming extruder (Toft, 1979).

A collet extruder is designed to produce expanded snacks using corn grits as the primary ingredient. The design of the screw and barrel grooves imparts an extremely high shear to the raw material. This results in the development of sufficient heat to produce gelatinization of the material. Therefore, it is not necessary to apply any external heat to a collet extruder (Toft, 1979). The high pressure produced in the extruder are released rapidly at the die head, causing the extrudate to expand when the extrusion temperature exceeds the boiling point of water. The collet extruder has several limitations. The short barrel, screw and the developed high shear limit the operation since only ingredients with a very low moisture content have to be used.

A fried collet extruder is similar to a baked collet extruder, but uses a frying process as the drying stage. The extruder gelatinizes and cooks the raw ingredients, which is generally corn, and partially expands the extrudate without inducing a very high porosity (Toft, 1979). The ready-to-eat snack is obtained after the extrudate is fried and flavoured.

A cooking and forming extruder is designed for producing snack products in a range of shapes and sizes. For example, potatoes to flour, flakes and granules. The extruder has a specific auger which offers more flexibility and control during the process. The extruder has also a jacket around the barrel and/or a hollow auger which provides cooling or heating during the extrusion process. The extrudate is dried half-product which needs deep frying to be in a finished form (Toft, 1979).

The single screw extruder operational feature can be divided into three sections: feed, compression and metering. The initial feed section receives and conveys the preconditioned food materials into the extruder. The raw ingredients are compacted into a plug, thereby removing air from the system. By decreasing the flight height on the screw or by adding a special restriction plate the screws become completely filled (Rossen & Miller, 1973).

As the screw turns, the raw materials enters the compression section where high pressure, heat temperature and shear exists. The channel between the screw and the barrel wall gradually becomes smaller and the pressure on the materials rises. At this section, several reactions, such as starch gelatinization, protein denaturation and plastification occur.

At the metering section, a steady flow is established, before the plasticised material is extruded process through the die. The pressure and temperature of the material usually increases dramatically during this section.

The basic working principle of single screw extruders is based on friction. Friction is used to generate the necessary heat to produce gelatinization and heat is also necessary to be able to convey the material to the die. If slip occurs at the barrel wall the material will not be conveyed. This limits the use of single screw extruder to mixtures with low fat content since high fat favours slip.

2.1.2.2 *Twin screw extruder*

In a twin screw extruder, two parallel screws rotate in an eight figure section barrel. In general, twin screw extruders are classified according to the direction of the screw rotation and the way in which the screws intermesh. The most common design are corotating intermeshing, counter rotating non intermeshing and conical intermeshing (Harper, 1986; Huber & Rokey, 1990). The fully intermeshing, corotating twin screw extruder has being widely adopted by the food industry (Straka, 1985; Harper, 1986). The twin screw extruders are a step ahead of single screw extruders as they can overcome their limitations, such as the use of a narrow range of raw materials and the effect of slip at the wall described in the previous section.

A twin screw extruder has an enhanced ability to convey food materials down the screw's length. In these machines, the screws can be configurated to enhance conveying, kneading, shearing, pressure development and filling of the screw. Conveying sections are usually only partially filled with product and therefore impart relatively little energy and shear. Kneading elements create a significant shearing/mixing action and dissipate large amounts of mechanical energy. Dams, reverse-pitch screw elements can be used to increase screw fill. The amount of shear imparted is affected by the kneading-block design. Shear increases with increasing numbers of lobes on the kneading blocks.

According to Shah & Campanella (1995), the main operational features in the twin screw extruder include feeding, screw configurations, screw speed, barrel temperature and die design. The material is fed by pumping or screwing into the extruder barrel and as the twin screw turns, the material is conveyed and subjected to mechanical and thermal stress which plasticizes the product when moves towards the die.

The screw configuration (screw design and position) can be manipulated in the twin screw extruder by considering the degree of barrel fill and mixing requirement, pumping efficiency, material rheological characteristics, residence time distribution, or cooking requirements (Shah & Campanella, 1995).

Although the screw configuration can be manipulated, the normal practice is to configure the screw as a series of repeated conveying and mixing elements. The conveying screws generate the pressure required by the material to flow through the mixing elements. The pressure differences combined with high temperature and mechanical stress change the material characteristics during the extrusion process (Shah & Campanella, 1995).

Because of the interchangeability of the screw geometry, the twin screw extruder offers more product diversifications than the single screw extruder. However cost could be the main constraint in making a decision on the purchase of a twin screw extruder. A twin screw extruder is 1.5 - 2.5 times more expensive than a single screw extruder.

2.1.3 Application

Until mid nineteenth century, extrusion cooking was commercially used for sausage meat and farinaceous products, expanded corn snacks and baked pet food biscuit (Harper, 1979). However the application of extrusion has substantially increased over the past decade (Shah & Campanella, 1996). The range of extrusion process application proposed by Camire *et al.* (1990) is shown in Table 2.1.

Table 2.1 Extrusion process application

Status	Application			
	Little nutritional concern	Avoid nutrient destruction; Increase starch digestibility	Destroy antinutrional and/or toxic factors	Prepare nutritionally enriched or balanced foods
Industrial	* Bread crumbs * Precooked starches * Anhydrous decrystallization of sugars to make confectioneries (hard candies) * Chocolate conching * Pretreated malt and starch for brewing * Stabilization of rice bran * Gelatin gel confectioneries * Caramel, liquorice, chewing gum	* Corn and potato snacks * Co-extruded snacks with internal filling * Flat crispbread (bread substitute, toasted bread) * Biscuits, crackers, cookies * Breakfast cereals and flakes * Precooked flours, instant tortilla flour, instant rice pudding * Cereal-based instant dry soup mixes or drink bases * Transformation of casein into caseinate	* Oilseed meals * Precooked soy flours (including full-fat soy flour; for enhancer of brad, pasta, etc)	* Animal feeds (Cattle, pet foods, fish food) * Precooked instant weaning foods or gruels (cereal/legume blends, such as CSM-WSB) * Texturized vegetable protein (TVP) * Dietetic foods (gluten-free, bran-enriched, etc)
Development	* Degermination of spices * Encapsulation or generation of flavouring agents * Enzymatic liquefaction of starch for fermentation into ethanol	* Quick-cooking pasta products * Oilseed treatment for subsequent oil extraction * Preparation of specific doughs (no retrogradation during cold or frozen storage)	* Destruction of alfatoxins or gossypol in peanut or cottonseed meal * Sterilization of blood meal	* Gelatin of vegetable proteins (high moisture) * Restructuring of minced meat * Prepare new sterile process cheese (high moisture, high fat) * Prepare sterile baby foods (high moisture)

Source: Camire *et al.* (1990)

2.2 THE FUNCTIONAL PROPERTIES OF RAW MATERIALS USED IN EXTRUSION COOKING FOR THE MANUFACTURE OF A SNACK PRODUCT

Extruded snack products were originally made from corn grits only. However, better knowledge of the extrusion process and improvements in equipment design have led the product developers to use other raw materials, such as rice and potato in coextrusion processes. In addition, to obtain better quality snack products, several process aids materials, such as water, oils, flavour and nucleating agents are added in the formulation.

Raw materials used to produce extruded snack products need special functional properties as the extrusion process has specific processing conditions, such as high compression and shear at high temperatures (Guy, 1994). Extrusion employs large mechanical energy and heat inputs in highly compressed powders systems which cause the powders to be transformed into fluids (Guy & Horne, 1988; Colonna *et al*, 1990). Characteristics, such as surface friction, hardness and cohesiveness of particles are important. In the melt fluid with high solids concentration developed within the screw system, the presence of plasticiser and lubricants, such as water and oil causes significant changes to the extruder process variables (Guy, 1994).

Matz (1976) lists the raw materials commonly used to produce extruded snacks (Table 2.2).

Table 2.2 Raw materials commonly used to produce extruded snacks

Raw materials	Characteristics
Corn	Corn has a good expansion rate and a typical corn flavour.
Rice	It expands readily into a low density, white and bland tasting product of crisp texture.
Oat	Due to its relatively high fat content, this cereal requires high moisture and high temperature for adequate expansion. The puffs have a fairly soft texture.
Wheat	Relatively high moisture and high temperature are needed to obtain satisfactory puffing performance. It does not expand as well as corn or rice.
Potato	It requires high moisture and high temperature, but it extrudes well under these conditions and forms snacks of excellent texture.
Tapioca	It gives bland tasting puffs when treated at high temperature and moderate moisture content.
Soy flour	It can be used as auxiliary ingredient with generally adverse effects on colour, flavour and texture.
Starches	Special starches, such as unmodified cereal starches, modified starch, pregelatinized starch and specialty starches high in either amylose or amylopectin are often added in a small amount to improve the extrusion process towards other materials or to change the product texture (Moore, 1994).

Source : Matz (1976)

Based on the functionality of each raw material characteristics, Guy (1994) classified the ingredients into six groups: structure forming agents, dispersion agents, plasticisers and lubricants, nucleating agents, flavouring and colouring agents.

2.2.1 Structure forming agents

The main structure forming agent in the extruded snack is obtained from cereal and root crops. The cereals which are commonly used for this type of food products are corn and rice, while the root crops are tapioca and potato.

Cereals are comprised mostly of starch, although they also provide a moderate level of protein; varying levels of fat and fibre; and low levels of sugar, vitamin and minerals (Moore, 1994). Starch provides the structure and texture of extruded products. This characteristic relates to the ability of the starch and protein components of the endosperm of the cereals to bind together into a strong cohesive mass (Guy, 1994).

Corn and rice contain 71 - 81% and 77 - 81% of starch, respectively. They have between 6 - 10% protein and less than 0.5% fibre and ash. Corn contains maximum 2% lipid, whereas rice contains less than 0.5%. These compositions depend on the crop varieties.

The corn starch granules can vary in a wide range of size and composition. Waxy corn contains very little amylose, whereas the normal corn contains levels of 25 - 35% amylose. Amylomaizes contain higher levels of amylose, comprising 50 - 70% of the starch. The amylomaize has a high gelatinization temperature (>120°C) in dilute dispersion with water, as the starch consists of hybrid polymers of amylose and amylopectin (Takeda & Hizukiri, 1989).

The rice starch granules are very small (2 - 8μm) and have a polygonal shape. The composition of the granules may vary widely, normal rice has 15 - 27% amylose and waxy rice varieties have almost 100% amylopectin. Rice flour provides a starch matrix for expansion. This allows alternative flavours to be added. The protein levels in rice flours or grits are relatively low (6 - 8%) and the protein is predominantly of the glutenin and gliadin types. Therefore, the performance of rice protein in extrusion cooking is fairly similar to corn in terms of the physical changes and chemical activity. In addition, rice has a level of expansion similar to that of corn.

Tapioca and potato starch are often used in snacks to provide better functional properties, such as extra dispersed starch to increase expansion. Their starch granules mainly consist of amylopectin, although potato starch may contain 20 - 25% amylose and very low lipid content (0.1 - 0.2%). Both of them are typically used as different starch sources to improve texture.

2.2.2 Dispersion agents or fillers

Dispersion agent or fillers are materials which modify the behaviour of the melt flowing through the die and the character of the cooled extrudates. These include protein, starch and fibrous materials (Moore, 1994).

Moore (1994) stated that protein can be automatically obtained from the cereal. The proteinaceous materials hydrate in the mixing stage of the process and become a soft viscoelastic dough during the melt transition. Under the influence of shearing forces in the extruder, the proteinaceous materials are macerated into small particles of roughly cylindrical and globular shapes and tend to reduce the swell at a low level of addition (5 - 15%). This causes changes in the shape of the extrudate and reduces the expansion at the die exit.

Starch which remains ungelatinised in the melt fluid, such as amylomaize, acts as a filler and causes a similar effect to the protein. Amylomaize has a high gelatinization temperature (>120°C). This starch may also increase bubble nucleation within the extrudates during expansion, thereby creating a finer texture.

Fibrous materials, such as bran from the outer layers of cereal grains may be made up of cellulose. These materials do not break down during extrusion and retain their size and shape. Moore (1994) stated that the addition of fibrous materials at the levels of 2-3% reduces the expansion of the extrudate and affects the product's shape.

2.2.3 Plasticisers and lubricants

The compression and shearing of natural polymers, such as starch or protein causes a large dissipation of mechanical energy, due to viscous and frictional effects. To reduce the loss of mechanical energy, plasticisers or lubricants are added. Water will act as a plasticiser (Nelson & Labuza, 1993; Guy, 1994; Moore, 1994), while oil, fat and emulsifiers act as lubricants.

As a plasticiser, water reduces the interactions between polymer compounds forming the ingredients, such as starch. It causes a decline in energy input in the low moisture range (10-25% w/w) and provides a solvent to diffuse into the starch granules. The starch becomes weaker and more easily dispersed (Guy, 1994).

Oil and fat in the ingredient mixture forms a dispersed phase outside the starch granules. This phase will have a lubricant effect when the mixture is sheared and compressed during the extrusion process (Guy, 1994).

For formulations containing flours, lubrication of the flour particles by the oil will protect the starch granules from dispersion. This could reduce the friction between materials and the extruder and decrease the specific mechanical energy input. Since the amount of dispersed starch in the continuous phase is reduced, the viscosity of the extrudate melt increases causing a reduction of the extrudate expansion (Guy, 1994).

Emulsifiers are forms of lipids which tend to have higher melting points than triglycerides, and provides lubrication in the extrusion process. Emulsifiers, such as glyceride monostearate and lecithin, interact with melted starch granules providing a protective layer at the surface, before the starch is dispersed. It reacts with the amylose fraction of the starch and gives a very insoluble compound which melts at a very high temperature. The compound will reform again during the cooling process. Emulsifiers also serve to reduce surface stickiness of warm extrudates (Moore, 1994).

Harper (1981[b]) reported that soy proteins are used extensively in extrusion because of their low cost, accessibility and widely varying functional properties. Soy protein is often used to increase the protein content of extruded cereal mixtures and improve the protein quality of the blend. Soy protein has a large amount of lysine, the essential amino acid which is deficient in cereals, while cereals have excess methionine, an amino acid deficient in soy protein, so the blend has the advantage of offsetting the deficiencies.

2.2.4 Nucleants for gas bubble formation

According to Moore (1994), to manipulate the texture of extrudates, nucleating agent can be added to a formulation. This nucleating agent help to form and increase the number of nuclei bubbles in the melt extrudate. The ideal types of nucleant are finely powdered food grade materials which remain insoluble during processing and provide surfaces at which bubbles may form during the release of water vapour. This agent includes baking powder which is made up of soluble salts of phosphoric acid and sodium or calcium salts. Lai *et al.* (1989) reported the addition of sodium bicarbonate to wheat starch improved extrudate expansion, but weakened its structure and caused browning.

2.2.5 Flavouring agents

Flavours are added to snack products to increase their eating quality. Harper (1979) classifies the flavouring methods as: (1) external application, (2) internal incorporation and (3) a combination of the above two procedures. Huber & Rokey (1990) described two types of external application methods: in the first method the extrudate is first sprayed with vegetable oil and then dusted with a variety of dry flavours and/or seasonings. The second method is different as oil, flavours and spices are mixed together in a tank and applied to the product as it is tumbled in a flavour application reel. External application is the most normally used as it has been found by far the most successful procedure.

Incorporation of flavours before extrusion has not resulted in acceptable flavour retention. Moist flavour compounds are very volatile and a substantial portion of their potency is normally lost with the steam flashed-off during the extrusion process. Microcapsulation of flavours was suggested to overcome this problem. However higher cost and only limited protection of flavours discouraged its application (Harper, 1979). In addition Matz (1976) claimed the addition of flavour during extrusion can undergo significant changes since interaction and chemical decomposition of the flavouring agent may occur as a result of the high processing temperatures.

From a processing point of view, incorporation of flavours to the raw ingredients would eliminate a messy and costly step following extrusion, however, technical feasibility of this practice on industrial scale has not been achieved (Harper, 1979).

A popular combination of flavouring agents used in snacks is oil, salt and cheese powder (Matz, 1976; Huber & Rokey, 1990). The oil gives the snack a better mouthfeel and the seasonings allow the manufacturer to make a variety of flavours.

The oil and seasoning coating usually makes up 35% of the finished product weight (Moore, 1994).

Salt and sugar can be included as flavouring agents. Addition of salt at levels of 1 to 1.5% of product weight is usually applied, although the precise level should be optimized in balance with the rest of the ingredients (Moore, 1994).

Sugar added can be in the form of glucose, sucrose, fructose and lactose. Reducing types of sugar, such as glucose, fructose and lactose are often used, since they can also act as colouring agents, through Maillard browning reactions occurring at high temperature. This reaction may also produce a range variety of flavours with both sweet and savoury character (Moore, 1994).

Sucrose may be added to formulations from low levels up to 10% w/w in extruded products without causing significant changes to the processing variables (Sopade & Le Grys, 1991). Its flavour becomes perceptible at levels more than 5%, but in order to produce sweet products, levels of 10 to 15% are required. Food grade gums are often added to the liquid sugar flavouring to produce greater viscosity and reduce loss during coating.

For products, such as potato sticks, the addition of flavouring agent is not necessary, as the raw material itself (potato) retains its characteristic flavour in the finished product. Ingredients, such as rice and tapioca, have bland taste, thus, additional flavours have to be added to the formulation.

2.2.6 Colouring agents

According to Moore (1994) colouring agents may be added to the formulations to obtain snacks with uniform and acceptable colour. The colour agents include natural and artificial colours. In addition, ingredients, such as caramelized sugar and milk powder can contribute to the product colour during processing.

Natural colours are generally unstable to heat. To achieve the desired results using artificial colours, it is required the amount of 30 and 600 ppm FD & C pigments (Kinnison & Chapman, 1972). Nevertheless, the difference in product colour can also be caused by physical fading. The foam structure causes a refraction of light which whiten or lighten the basic colour of the material. The smaller the bubbles, the lighter the colour (Matz, 1976).

2.3 RAW MATERIAL PROPERTIES CHANGES DURING EXTRUSION PROCESS FOR AN EXPANDED SNACK

2.3.1 Starch degradation

Native starch granules are insoluble in cold water, although they can swell slightly and become partially hydrated. The granules swell more when they are heated and reached a specific temperature, i.e. glass transition temperature (Biliaderis, 1991).

In an excess water environment (above 63% moisture), the starch absorbs more water and the granules continue to expand/swell above the melting temperature. The viscosity of the suspension dramatically increases. This sequence of granule transformation is known as starch gelatinization (Donovan, 1979; Harper, 1981[b]; Wang *et al.*, 1991; Waniska & Gomez, 1992).

According to Donovan (1979) the starch granule structure contains both crystalline and amorphous regions. During the starch gelatinization process, the water first penetrates in the amorphous region. This region swells and promotes the transformation of crystalline regions by pulling the crystallites apart. Therefore gelatinization entails the loss of crystallinity of the granule (Priestly, 1975).

In a limited moisture environment (less than 30%) complete gelatinization does not occur at the normal gelatinization temperature range. However as the starch is heated, the granules become progressively more mobile and eventually the crystalline regions melt (Donovan, 1979; Lai & Kokini, 1991; Wang *et al*, 1991). Thus, in a limited moisture environment with heat treatment, the starch transformation is due to melting. During the melting, the hydrogen bonds of starch interchain with water through an adsorption mechanism. The adsorption results in the growth of the crystalline regions which inhibits moisture penetration. As the result, the gelatinization temperature range is increased (Lai & Kokini, 1991).

Studies on the transformation of extruded starch by Anderson *et al.* (1970); Mercier & Feillet (1975); Chiang & Johnson (1977); Lai & Kokini (1990) suggested that the loss of crystallinity was caused not only by the excess of water, but also by mechanical disruption of the molecular bonds through the intense shear fields within the extruder.

In the extrusion process, starch is subject to high temperature, high pressure and high shear conditions. These conditions produce starch transformation: such as gelatinization, melting and fragmentation. Gelatinization occurs if moisture is available in the system, while melting occurs at low moisture content. The high shear produces granule starch fragmentation (Wen *et al.*, 1990).

Starch fragmentation is a partial or complete destruction of the granule crystalline structure (Lai & Kokini, 1991). Meuser *et al.* (1978) suggested that the starch fragmentation is the produced by the action of mechanical energy. The mechanism of fragmentation is reported to be in the form of a limited debranching in amylopectin (Davidson *et al.*, 1984[a], 1984[b]) or random chain splitting in amylose (Colonna *et al.*, 1984), which causes significant decreases in overall molecular size (Meuser *et al.*, 1978). Wen *et al.* (1990) stated that the amount of linear polysaccharide increased after extrusion.

Extrusion of snacks and breakfast cereal is normally conducted at low moisture contents ranging from 12% to 16% wet basis and short residence time (20-200 seconds). Under these conditions, the loss of crystallinity is more likely caused by mechanical disruption (Camire *et al.*, 1990; Wen *et al.*, 1990; Mitchell & Areas, 1991). The shear forces physically tear apart starch granules and allows faster transfer of water into the starch molecules (Burros *et al.*, 1987). Therefore, extrudates produced at low moisture content are a mixture of gelatinized, melted and fragmented starch (Lai & Kokini, 1991). In the case of products made from cereal starches, formation of amylose-lipid complexes can also occur and exist in the final product (Mitchell & Areas, 1992).

The rate of formation of gelatinized fractions follows first order kinetics whereas the formation of melted fractions follows zero order kinetics. The overall reaction rate follows zero order kinetics as melting is the dominant mechanism under low moisture extrusion (Qu & Wang, 1994).

Operation conditions include barrel and die temperature, screw speed and screw geometry. The feed composition such as amylose-amylopectin ratio, moisture content have also a profound influence on the mechanical disruption and starch transformation (Lai & Kokini, 1991).

The effect of the operational conditions and feed composition on the starch degradation is measured through the extrudate starch molecular solubility or starch dispersion (Waniska & Gomez, 1992).

The effect of pressure on Amioca corn starch has been studied using differential scanning colorimetry (DSC) and rheological techniques (Kokini *et al.*, 1990). The results indicate that amylopectin is much more sensitive to changes in pressure than other molecules.

2.3.2 Protein denaturation

Protein is composed of amino acids which contain both amino and acidic carboxyl groups. The amino acid varies depending on protein sources. Each amino acid possess as dipolar characteristics: polar and unpolar groups (Angemier & Montgomery, 1976). Polar groups are recognized as hydrophillic as the carboxyl groups can bind water through hydrogen bonds. Thus, they are generally soluble in aqueous solutions. The unpolar groups are less soluble in water and tends to be hydrophobic.

Protein compounds are subject to denaturation under denaturing agents: water, pH and heat (Singh, 1994). Denaturation is a process by which hydrogen bonds, hydrophobic interactions and salt linkages are broken. The denaturing agents disrupt bonds which are essential to the maintenance of three-dimensional protein structure. The structure becomes asymmetrical and the protein molecule is unfolded, thus exposing hydrophobic groups. The exposed hydrophobic compounds produces aggregation of the denatured protein and decreases the protein solubility (Angemier & Montgomery, 1976).

In the extrusion process, factors such as heat treatment, feed moisture and increase residence time encourage the protein denaturation and reduce solubility (Camire *et al.*, 1990). Heat treatment provides energy to the system, thus facilitating protein bonds rupture. The molecule of either hydrophillic or hydrophobic groups tend to open up and unfold (Singh, 1994).

In the presence of water hydrophillic groups react with water leaving the hydrophobic groups exposed. Five to ten percent water is sufficient to start denaturation (Angemier & Montgomery, 1976; Singh, 1994). It has been found that moisture plays an important role in protein denaturation during extrusion (Sheard *et al.*, 1984; 1986).

Extrusion cooking affects protein properties which leads to the changes in product characteristics (Harper, 1981[b]). Cumming *et al.* (1973) observed that water-soluble proteins in soy bean meal become insoluble and/or break into sub-units of smaller molecular weight during extrusion.

The formation of new disulphide bridges and the changes in hydrogen bond dominate in the protein denaturation at extrusion temperatures below 150°C, however, at higher temperatures intermolecule peptide bonds may also be formed (Hager, 1984). Both disulphide and hydrophobic bond interaction play an important role in stabilizing the extrudate structure (Sheard *et al.*, 1984), as well as electrostatic interactions (Prudencio-Ferreira & Area, 1993). The formation of disulphide bond also suggested the reduction in nitrogen solubility in texturized legume flours extrusion (Pham & Del Rosario, 1984). Products with higher protein contents have lower nitrogen solubility, which is attributed to greater denaturation and thus aggregation of protein molecules (Camire, *et al.*, 1990).

Past research has shown that extruded soya losses a large amount of lysine after extrusion (de Muelenaere & Buzzard, 1969; Noguchi *et al.*, 1982; Björck *et al.*, 1984 and Pham & Del Rosario, 1986). Noguchi *et al.* (1982) noted that the retention of lysine available in protein enriched biscuits is affected by the feed moisture. Pham & Del Rosario (1986) reported higher losses of available lysine in extruded legume flours when temperature was kept constant and the moisture of the mix was increased. Lysine present in the extrudate increases with increase in screw speed because decrease the residence time in the extruder. In addition, Björck *et al.* (1984) proposed the loss of lysine in extrusion was mostly due to the protein-starch interaction. The presence of water hydrolyse the starch and form reducing sugars. Lysine and reducing sugars interact together in Maillard reaction to produce browning of the product. The interaction between protein-polysaccharide is described further in the next section.

2.3.3 Protein-carbohydrate interaction in the extrusion process

The availability of protein and reducing sugar during heat treatment establishes a Maillard-browning reaction. The Maillard reaction is a nonenzymic browning reaction between free amino acids of protein, such as lysine and methionine, and reducing sugars of carbohydrate, such as glucose, maltose and lactose. The Maillard reaction is very complex and of consists several reaction stages, thus a wide variety of compounds can be produced during this reaction (Angemier & Montgomery, 1976).

During extrusion, the Maillard reaction is favoured by conditions of high temperature (>180°C) and shear rate (>100rpm) in combination with low moisture (<15%) (Camire *et al.*, 1990). Phillips (1989) suggested that the Maillard reaction is most likely to occur in the manufacture of expanded snack. The reaction produces a brown colour in the product which improves palatability (Kim & Maga, 1987) but reduces the protein solubility of the extrudate (Phillips, 1988).

The brown colour produced could be the effect of melanoidins and other compounds produced during the reaction. Björck *et al.* (1984) found higher reflectance values, which indicates lighter colour, is correlated with total lysine content of extruded wheat. In the case of breakfast cereals made from wheat flours, a positive correlation between Hunter *L* value and the available lysine (McAuley *et al.*, 1987) was found.

The effect of available carbohydrate in soya flour extrusion was studied by Sheard *et al.* (1984). A comparison between soya isolate extruded and defatted soya flours showed that the carbohydrate components in defatted soya flour modify the properties of the proteinaceous melt within the extruder and bind together within the protein matrix, leading to a decrease in water uptake and carbohydrate solubility as the temperature is increased. The carbohydrate-protein bond provides a more uniform distribution of air cells.

2.3.4 Rheology properties

Rheology can be defined as the science of the deformation and flow of materials under the influence of forces (Shah & Campanella, 1995). In extrusion cooking, rheology properties of raw materials has a direct effect on extrusion process design and the extrudate characteristics.

Food extrusion is a continuous flow process and many changes occur along with the material flow which affects the end product, particularly its texture profile characteristics. When raw materials flow through the barrel, their macromolecules, such as starch and protein, are denatured and align themselves along the streamlines in a laminar flow until reaching the die (Harper, 1986).

In low moisture extrusion, ingredient molecules degrade and crosslink to form the fabricated structure when comes out from the extruder die. The resistance of the fabricated structure indicates the type of chemical bonds structure. Weak hydrophobic and hydrogen bonds can be easily disrupted with water, while stronger covalent and ionic bonds resist the disruption and retain the product texture (Harper, 1986).

The effect of extrusion variables (moisture, temperature and screw speed) on the viscosity of the extrudate melt are described with equation models (Shah & Campanella, 1995). An increase in feed moisture and temperature at a given screw speed reduces the extrudate viscosity and pressure. Extrudate melts are shear thinning materials and their viscosities decrease with increase in the screw speed.

The effect of extrusion conditions on texture profiles using sensory tests was studied by Chen *et al.* (1991). The denseness of extrudates is affected significantly by the barrel temperature during extrusion and by the interaction between temperature and screw speed. At high temperatures and long cooking times the viscosity of the melt is low and results in an increase in product expansion. At low temperatures, the raw materials become more viscous resulting in less expansion of the extrudate products (Chen *et al.*, 1991).

The crispiness of extrudates is closely related to denseness characteristics. The response of crispiness to screw speed and temperature is opposite to denseness. Sensory evaluation has shown that higher screw speed gives higher crispiness scores. This is because increases in screw speeds results in larger energy input causing more stretching and fracture of the protein-protein matrix. At a given temperature, increasing the moisture content of raw materials resulted in decreased crispiness in the extrudates (Chen *et al.*, 1991).

It has been recognised that the extent of puffing occurring during extrusion is related to the pressure difference between the die and the atmosphere. Foods with lower moisture tend to be more viscous than those with higher moisture and, therefore the pressure difference is smaller for higher moisture foods, leading to a less puffed product (Chen *et al.*, 1991).

2.3.5 Specific Mechanical Energy

The screw rotation produces mechanical dissipation energy, as the result of the friction (Harper, 1986). Although the mechanical energy is converted to thermal energy, its impact on the product characteristics is not only through the heat treatment, but also through the shear effects (Kokini, 1993).

The amount of energy can be calculated using the following formula :

$$SME = \frac{T * \omega}{F}$$

where:

SME	=	Specific Mechanical Energy (W.hr/kg)
T	=	Torque (N.m)
ω	=	Screw speed in angular velocity (1/sec)
F	=	Feed rate (kg/hr)

The mechanical energy catalyses a number of reaction, such as starch degradation (Kokini, 1993). By taking account the Specific Mechanical Energy formula given above, the effect of feed rate and screw speed on the ingredients changes in properties can be indirectly predicted.

According to Hsieh *et al.* (1993), increases in the screw speed could either increase or decrease the Specific Mechanical Energy requirements. The total power transmitted from the main motor to the screws is the power dissipated into the material as shear (Martelli, 1983).

2.4 EXTRUDATE PROPERTIES ASSESSMENT

2.4.1 Water Absorption Index (WAI) and Water Solubility Index (WSI)

During the extrusion process, the long polysacharide chain of starch is damaged (melted, gelatinized and/or fragmented). This damaged starch exposes the hydrogen bonds which causes the extrudate to absorb moisture from the environment. The gelatinized starch can solubilize in water more easily than the ungelatinized starch (Lai & Kokini, 1991). Therefore, water absorption index (WAI) measures the capacity of damaged starch to absorb water and water solubility index (WSI) measures the amount of starch that has been solubilized by the gelatinization process.

The WAI measures the amount of gel obtained from the sample after the sample is suspended in water and centrifuged. While the WSI measures the amount of solids in the sample that is solubilized during the sample suspension (Anderson *et al.*, 1969).

WAI and WSI are often used to measure the starch transformation on corn grits or corn starch during processing, such as roll cooking, steaming and extrusion process (Anderson *et al.*, 1970).

In extruded cereal products, WAI & WSI are used as an indicator of the starch modification by temperature, moisture and starch composition (Mercier & Feillet, 1975).

Temperature increase during the extrusion process, transforms more starch granules, thus the WAI and WSI increases (Mercier & Feillet, 1975; Owusu-ansah *et al.*, 1983; Kim & Maga, 1987; Chauhan & Bains, 1988). A similar trend occurs with increased temperature and moisture content (Owusu-ansah *et al.*, 1983), while a higher feed moisture resulted in slightly higher WAI (Kim & Maga, 1987).

Owusu-ansah *et al.* (1983), using corn starch, found that at higher level of moisture feed and higher screw speed, the product water solubility index (WSI) increases. However there appears to be discrepancies in the literature as for cassava flours, WSI decreases and WAI increases as the screw speed is increased (Badrie & Mellowes, 1991[a]). Screw speed affects the starch transformation into two ways. A high screw speed provides high shear which tears apart starch granules (Burros *et al.*, 1987). On the other hand, it reduces residence time which could reduce the starch transformation reaction (Chiang & Johnson, 1977).

2.4.2 Nitrogen Solubility Index (NSI)

The solubility of protein decreases during the extrusion process, due to heat and shear denaturation and possible interaction with carbohydrates. The reduced solubility of protein in the extrudate product is indicating the change of protein properties during extrusion. Therefore, measuring the solubility of an extruded protein can indicate the degree of protein denaturation, as how the protein denatures is the effect on functional capabilities (Camire *et al.*, 1990).

Various methods have been used to measure protein solubility and some of the methods have been standardized, such as the method described in AOCS Method Ba 11-65 (1973). The ground extrudate is stirred in a solvent, and after centrifugation the supernatant is subjected to Kjedhal analysis for nitrogen content. The majority of research has focused on soya protein solubility (Camire *et al.*, 1990).

Decrease solubility compared with that of unextruded materials has been reported for extruded corn/soya blends (Maga & Lorenz, 1978); for extruded corn/soy/whey mixtures (Aguire & Kosikowski, 1978).

2.4.3 Glass transition temperature (Tg)

Macromolecules such as polysacharides and protein are subject to disruption into smaller molecules during the extrusion process. It has been well-established that the glass transition temperature (Tg) of a polymer is related to the molecular weight of the polymer (Donald & Warburton, 1993; Kaletunc & Breslauer, 1993). Thus, measurement of extrudate glass transition temperature could characterize changes occurred on the macromolecules forming the product during the extrusion process.

Glass transition temperature (Tg) is defined as a transition from a brittle metastable, glass state to an unstable, amorphous state (Kaletunc & Breslauer, 1993).

The glass transition temperature (Tg) of the extrudate could be detected by differential scanning calorimetry (DSC).

DSC detects the energy required by the sample to maintain an equilibrium temperature between the sample and a blank (empty pan). The energy increases as the temperature increases. At the glass transition state, more energy is required since it is used not only for the temperature equilibrium but also for transition of the sample structure.

Kaletunc & Breslauer (1993) found that the glass transition temperature of extrudate is lower than that of the unprocessed feed ingredients as the result of macromolecule disruption. Consequently, the more molecules disrupted during the extrusion process, the lower Tg will be.

Kaletunc & Breslauer (1993) found a correlation between the extrudate's Tg and Specific Mechanical Energy (SME). An increase in SME produced a decrease in Tg. The increase in Specific Mechanical Energy provided during processing gives an indication that more molecules have been disrupted.

Nelson & Labuza (1993) and Kaletunc & Breslauer (1993) reported a correlation between Tg and extruded snack's texture. The increase in crispiness can be related to an increase in Tg.

2.4.4 Texture measurement

Texture is one of the important quality attributes of expanded snack. The texture of the extruded food product is affected by the shear environment in the extruder screw and die, the type of ingredients and the condition (time and temperature) required for chemical crosslinking of the molecules (Harper, 1986).

As mentioned before the shear applied in the extruder damages the macromolecules of food compounds. This damage effect may reduce their ability to expand, increase water solubility and reduce functionality, creating softer textural characteristics (Harper, 1986).

Several methods are used to measure the extruded texture profile instrumentally (Halek *et al.*, 1989; Halek & Chang, 1991). The methods include the measurement of fracturability, cohesiveness, springiness, gumminess and chewiness. Those profiles are basically measured during a compression test and the explanation of those texture parameters are described in Bourne & Comstock (1981). Kango (1992) measured the rheological properties of extruded corn snack using a Warner Bratzler shear cell and compression in an Instron Universal Testing machine.

Load required to shear through (shearing strength) and load required to break (breaking strength) are used to measure the textural characteristics of wheat flour extrudates (Faubion & Hoseney, 1982). The shearing strength is measured with a Warner-Bratzler shear apparatus to shear across the extrudate, while the breaking strength is measured as the force required to break the extrudate which is placed between two supports. Although both methods provide a good explanation, the breaking strength gives a better replication in the analysis (smaller variance) than the shearing strength. Chauhan & Bains (1988) also used breaking strength and fracturability to measure the texture of extruded rice-legume blends.

2.4.5 Colour measurement

Colour and overall appearance is an important attribute of snacks, besides flavour and texture. Colour is normally measured through analysis of the light reflection from a food surface or light transmission through the food (Francis, 1977).

Several colour classification systems are available to identify a product colour:

Hunter L^*, a^*, b^* system, Munsell notation system and CIE system. Each system basically determines the colour sensation which is regarded as the union of three distinct qualities, defined as hue, lightness and saturation.

Hue is defined as the intensity of a particular type of colour. Lightness is the impression of the relative amount of the incident light reflected from the surface. Saturation is defined as the degree of difference from grey at the same lightness.

In the Hunter L^*, a^*, b^* colour measurement system, L^* refers to lightness or darkness, a^* refers to the degree of redness/greenness and b^* refers to the degree of yellowness/blueness. A colour difference parameter (ΔE^*) among L^*, a^*, b^* could be calculated.

In extrusion cooking, the colour of the product is a consequence of the functional changes which occur during the process. Chen *et al.* (1991) observed colour changes in extruded corn meal and described three major causes for colour changes of corn meal during extrusion: (1) decomposition of corn pigments; (2) product expansion causing colour fading; (3) the colour produced as a result of chemical reactions, such as caramelization of carbohydrates, the Maillard reaction and the effects of oxidative decomposition products of lipids and proteins.

2.5 CONSUMER AND MARKET RESEARCH

It is necessary to consider the market and consumer when developing a new product to determine the opportunity of product success in the market. Information on the market situation and consumer behaviour either the past or present can be obtained by conducting market and consumer research.

Consumer research provides descriptive data about consumer behaviour, attitude and opinion towards the present and new products (Meiselman, 1994), while market research is a tool to discover the reason for consumer purchasing behaviour, attitudes and intension towards a particular product. Market research is also used to identify problems for current and new product concepts and to determine the possibility of a new product sale (Robertson, 1987; Crossley, 1991; Earle, 1994)

2.5.1 Data collection in market and consumer research

According to Kotler & Armstrong (1991) the process of market research consists of four steps: (1) defining the problem and research objective; (2) developing the research plan; (3) implementing the research plan and (4) interpretating the findings.

2.5.1.1 *Research objectives*

Defining the problem and research objectives is often the hardest step as a wrong problem definition would lead to an unrelated conclusion and wrong action as well as it would be costly and time wasting (Kotler & Armstrong, 1991; Smith, 1991). The most common market research objectives include: to measure new product acceptance and its market potential, to determine market characteristics, to study competitive products, and to measure the market potential and market share (Kotler & Armstrong, 1991).

2.5.1.2 *Types of data collection*

The second step of the market research process is to determine specific information required and to select the method for collecting that information. The information could be gathered from secondary data, primary data or both. Secondary data consists of information that already exists or has been collected for another purpose, such as commercial data base from commercial research houses, periodicals, magazines, government publications and internal company records/reports.

Secondary data can usually be obtained more quickly and at a lower cost than primary data. It provides a good starting point for research and often help to define problems and research objectives (Kotler & Armstrong, 1991).

Primary data is the information which is purposely collected, to meet the research objective. It provides a more relevant, accurate, current and unbiased information. The data could be approached through observational research, survey research and experimental research. The observational research is set by observing relevant people, actions and situations, for example observing the shelf space and display support of a product in the supermarket and finding out the prices of competing brands. Observational research can obtain information that people are unwilling or unable to provide, but it can not evaluate consumers feelings, attitudes or motives. Therefore the observational research is normally conducted along with other data collection methods, such as survey research (Kotler & Armstrong, 1991).

Survey research is best suited to gather descriptive information, such as people's knowledge, preference, attitude or buying behaviour. Survey research can be structured: asking respondents to fill in a questionnaire; or unstructured: a direct interview and use their answer as the guide of the interview progress. Survey research is the most widely method used for primary data collection because of its flexibility. It can obtain many different kinds of information in a shorter time and at lower cost than observational or experimental research. However, survey research also presents some shortcomings, such as people that are unwilling to respond the questions, unable to remember about what they do, and dishonest in providing the information. Careful survey design can help to minimize these problems (Kotler & Armstrong, 1991).

Experimental research is set to provide an explanation on a cause and effect relationships (causal information). For example the effect of different prices on the product sales (Kotler & Armstrong, 1991).

In this project, the information on the snack market in Indonesia was obtained from secondary data: magazines, newspapers and journals; and primary data: by observing competitive products in the market, shelf space occupied in supermarkets, interviews with people from commercial companies and potential consumers and structured survey research with potential consumers.

2.5.1.3 *Research implementation*

Research implementation involves collecting, processing and analysing the information (Green *et al.*, 1988; Kotler & Armstrong, 1991). The data collection phase is generally the most expensive and subject to error. It is critical that the research be conducted with the product potential consumers and an adequate number of people be involved to allow a proper statistical analysis.

Anderson *et al.* (1984) recommended three principles that should be followed to obtain useful data, regardless what techniques and technologies are used in collecting data. These principles include (1) ask the right questions to the right people in the right way; (2) obtain answers to questions and relate the answers to the needs; and (3) communicate the data effectively.

Asking the right questions could provide information that would answer the objective of the research. Questionnaires and interviews should be prepared and pilot-tested to ensure consumers understand the questions. Asking opinions to a small number of people can help a consumer researcher to define the issues to be measured in a following-up structured interviews and questionnaires (Meiselman, 1994).

2.5.1.4 *Data interpretation*

Data interpretation is an important phase of the marketing process. The information is reported to the user in a form so that it can answer the research objective and be applied to the relevant issue (Anderson *et al.*, 1984). The difficulty in consumer research is not in measuring the opinion, but in interpretating that opinion into a decision. For example people who like a product are not necessarily going to buy or use it, or, people who do not like a product might be able to be persuaded to try it through advertising (Meiselman, 1994). This situation can cause a difficulty in determining the market size and target consumers.

2.5.2 Product attributes and product position in the market

The information obtained from market and consumer research is used to determine whether the product development should be carried out on the product and what product characteristics are expected by the consumers.

Product characteristics are product features that can be recognized by the consumers. These include physical product characteristics (e.g. size, shape and colour); chemical/ingredients composition; sensory characteristics (e.g. taste, sound in the mouth and aroma) and nutritional value (Earle, 1994).

The product characteristics that are recognized and valued by the consumers are described as product attributes (Earle, 1994). The product attributes are considered to be important in developing a new product. In other words, the product attributes should provide benefits to the consumers and thus, a product has a higher possibility of success in the market if its attributes meet the consumer's requirements. In positioning a product in the market, it is essential to relate the consumer interests and the benefit of the product (O'Connell, 1972).

2.5.3 Sensory techniques

Sensory evaluation is carried out using the senses when food is consumed due to sound, taste, aroma, appearance and touch (Larmond, 1977). The complex sensation that results from the interaction of human/panellist senses is used to measure food characteristics for quality control and new product development purposes.

Sensory testing can be helpful in product development by minimizing the risk in decision making. Panellists can identify sensory characteristics that help to describe the product (Baker *et al.*, 1988). They can confirm the necessary changes in ingredient formulation, identify areas for improvement, determine if optimization has been achieved, evaluate competitive products, observe changes occurring during processing or storage and provide data to substantiate advertising claims (Blair, 1978; Erhardt, 1978).

Several different sensory evaluation techniques have been developed (Larmond, 1977; Meilegaard, 1987[a]; 1987[b]; O'Mahony, 1988). The selection of a technique used is dictated by the testing purpose and the information required. The type of techniques, panellists, test implementation, data analysis and interpretation for food sensory evaluation have been comprehensively explained by Larmond (1977) and Meilgaard *et al.* (1987[a]; 1987[b]) and several examples of sensory evaluation application on food quality control and product optimization have been described by Moskowitz (1983; 1994), O'Mahony (1988), and Cardello (1994).

2.5.3.1 *Techniques for measuring sensory response*

There are three fundamental types of sensory tests: preference/acceptance test, discriminatory/difference test and descriptive test. Preference/acceptance test is based on the panellist's response about the product acceptance or his/her liking feeling towards the product. The most commonly used preference test is a hedonic preference test with a scale of five, seven or nine points (Larmond, 1977).

Discriminatory/difference test is used to determine whether a difference exists between samples based on the panellist's personal response. Discriminatory tests include ranking test, ratio-scale test, rating test and scoring test.

A descriptive test is used to determine the intensity of the differences (Larmond, 1977). An example of descriptive test is the line scale test.

Several sensory methods: hedonic preference test, line scale test, ranking test and *just right* scales test were used in this study. These tests are described in sections 4.4.3 - 4.4.5, together with the sensory techniques used in this study.

2.5.3.2 *Consumer panel*

In sensory evaluation, people are adopted as the measuring tool and called panellists (Larmond, 1977; Meilgaard *et al.*, 1987[a]). The panellists can be included in trained and untrained panels. The trained panels are used for product control purpose: to evaluate the product quality and product improvement, while the untrained, consumer, panels are used to determine consumer reaction to products, such as acceptance test (Larmond, 1977; Meiselman, 1994).

Meiselman (1994) recommended that acceptance test using hedonic and other affective scales should be done with untrained consumer panels only. Unfortunately, untrained consumers are more likely to produce a large variability in the results. The variability in responses may occur among panellists or even within their judgement over a period of time, thus it could lead to a misinterpretation of data (Meilgerald, 1987[a]). For this reason, the result of the sensory evaluation can not be directly interpretated, instead it must be tested by statistical analysis, such as t-test, ANOVA and Chi-square distribution. The statistical analysis is normally expressed in degrees of significance, which shows the probability that the results are caused by chance (Larmond, 1977).

The panellists who test the product should represent the potential target consumers (Meiselman, 1994). The number of panellists should conform the representative number in the population distribution so that it can be analyzed statistically. Meilegard (1987[a]) suggested 20 to 30 panellists are often used for sensory evaluation.

2.5.3.3 *Environment*

Sensory testing can be conducted in either supervised environment (central location/laboratory) or in-house test (unsupervised environment) (Meilseman, 1994; Moskowitz, 1994). Each environment has advantages and disadvantages which are described in Table 2.3.

Table 2.3 Advantages and disadvantages of central location and in-house test environment

Advantages/ disadvantages	Central location	In-house test
Advantages	* under controlled condition/supervision * careful product preparation * many products can be evaluated in a short period of time	* more natural & realistic environment * can measure long-term responsiveness to a product * better motivation
Disadvantages	* not a natural environment * for product which needs a preparation, it may not be prepared in a manner that the respondent is accustomed to * panellist can be affected by other respondents * can not measure long-term responsiveness to a product	* unsupervised rating of the products and product preparation * many products can not be evaluated over a short period of time, however, it can be overcome by sending all the samples and asking to test products over a period of time

Source: McDaniel & Sawyer (1981); Meyer (1984); Moskowitz (1994)

2.5.3.4 *Correlation between sensory evaluation with objective measurements*

Several studies have been conducted to correlate sensory evaluation with objective measurement (Langlais *et al.*, 1977; Von Sydow & Akesson, 1977; Moskowitz, 1983). Correlating the human sensory perception with objective measurement could lead to a better scientific understanding and could provide the necessary information to generate predesigned sensory characteristics (Moskowitz, 1983).

Correlations between sensory analysis and instrumental measurements, such as the Warner Bratzer shear test and HPLC measurements in texture and flavour studies often follow a linear relationship. In many cases high coefficient correlation ($r \geq 0.7$) is obtained on observation of single textural or flavour attributes. However a lower coefficient correlation ($r \leq 0.2$) can also be found in some objective measurements. A correlation of 0.8 or more is rarely found when one evaluates a wide cross section of different types of related stimuli (overall sensory characteristic) to the physical measurement (Moskowitz, 1983).

Acceptability tests are frequently fitted by non linear equations instead of linear equation for predicting overall liking (Moskowitz, 1983). Acceptability follows an inverted U shaped curve when plotted against the proportion of an ingredient or against a sensory characteristic. The acceptability or quality increases by increasing an ingredient level and reach an optimum condition. Afterwards, the acceptability decreases with the increase of ingredient level. For example addition of sugar will improve the sweetness and acceptability of a product until it reaches an optimum condition, then the acceptability start decreasing as the amount of sugar increase.

The primary concern in obtaining a relationship between objective and subjective measurements is to find objective measurements that can provide a good prediction of the product acceptability and preference. Since the bottom line in the food product development is to answer *Does the consumer like the product?*, there is no question that the human response should be considered during the product development process.

2.6 PRODUCT OPTIMIZATION

In food product development, the market driven process which is influenced by current consumer needs and trends forces food companies to respond rapidly to market place changes. A systematic experimental design is required to save the time consumed between product concept and market place (Arteaga *et al.*, 1994). This systematic experimental design is essentially a product optimization which considers the potential alternatives within problem constraints and provides a tool in deciding the best possible alternative (Norback & Evans, 1983; Beausire *et al.*, 1988; Arteaga *et al.*, 1994).

Norback & Evans (1983) divided the optimization concept into three major components: objective function, decision variables and constraints. Objective function is used by the decision maker to quantitatively compare the possible solutions and select the optimum. In food formulation problems, the objective function includes cost optimization (Smith *et al.*, 1984; Beausire *et al.*, 1988; Uaphithak, 1994) and maximization of consumer acceptability (Fishken, 1983; Sidel & Stone, 1983; Uaphithak, 1994).

Decision variables are the inputs required for the solution of a decision problem. In product formulation, the amount of ingredients used are the decision variables since they define the solution (Norback & Evans, 1983).

Constraints are restrictions placed in the formulation. They control the possible solutions to the problem by defining criteria that all solutions must meet, such as nutritional or legal requirements, processing constraints, etc. An alternative which satisfies all the constraints is said to be feasible (Norback & Evans, 1983).

Several methods for product optimization such as Taguchi orthogonal method, factorial design, mixture design and linear programming are reviewed by several authors (Norback & Evans, 1983; Sidel & Stone, 1983; Graf & Saguy, 1991; Arteaga *et al.*, 1994). Linear programming and mixture experimental designs are used in this study.

2.6.1 Linear programming

2.6.1.1 *Definition and application of linear programming in product optimization*

Linear programming (LP) is a mathematical technique for optimizing problems involving a linear objective function with linear constraints on the variables (Norback & Evans, 1983; Beausire *et al.*, 1988; Arteaga *et al.*, 1994). It is mainly used to find least cost formulations that meet specific linear constraints (Norback & Evans, 1983). In food product optimization, linear programming has been used for formulation of ice cream, beer and cereal (Norback & Evans, 1983); nutritive, low cost cereal based foods (Traver *et al.*, 1981; Valencia *et al.*, 1988); a low cost, fresh turkey sausage formulation (Beausire *et al.*, 1988).

Some researchers demonstrated that the formulation could be optimized by linear programming, even though some properties are non linear (Arteaga *et al.*, 1994). However Arteaga *et al.* (1993) and Chen *et al.* (1993) reported that because linear programming can not consider interaction effects between the ingredients, the optimization of functionality attributes of formulations using linear programming must be performed with caution. In addition Fishken *et al.* (1983) stated product acceptability is nonlinearly related to ingredient levels and therefore linear programming can not accommodate these relationships.

2.6.1.2 *The structure of linear programming in formulation*

In food formulation using linear programming, each decision variable identifies the quantity or percent of an ingredient to be used in the formulation. The value of these variables takes on any value between the upper and lower limits set in the constraints. The constraints include the sums of constant multiples of the ingredient (decision variables) compared to other constant numbers. An example of a constraint is $3.7\ X_1 + 2.1\ X_2 \leq 18$. The comparison is in terms of less than or equal to (≤), equal to (=) and greater than or equal to (≥) expressions. The variables in the constraints are raised only to the first power. Constraints that contain expressions such as X_1^2 or X_1X_2 can not be handled by ordinary linear programming design. The objective function is also the sum of constant multiples of the ingredients, but is not compared to any constant number. In the case of cost function, the objective function is the decision variables multiples by the cost per unit of each ingredient.

2.6.2 Mixture experimental design

2.6.2.1 *General mixture experiment*

Many products are made from mixtures of several ingredients. The characteristics of those products such as product quality and product performance depend on the relative proportions of the ingredients in the mixture (Cornell, 1983). In this type of situation, a mixture experimental design is required as opposed to the factorial experiment design.

In the mixture design, the variable is performed by combining together several ingredients. Unlike factorial design, the feature of mixture design is that the independent or controllable variables represent proportionate amounts of the mixture rather than unrestrained amounts (Hare, 1974).

Hare (1974) and Cornell (1983) explained comprehensively the mixture design concept. This design has been used in several projects such as: lemon juice, fish patties and gasoline (Cornell, 1983); fish cracker formulation (Anderson, 1985); ingredient interaction effects on protein functionality (Arteaga *et al.*, 1993).

2.6.2.2 *Structure of mixture experimental design*

The variables in the mixture design are described in proportions and the sum of all proportion variables is always 1 or 100% (Hare, 1974; Cornell, 1983; Anderson & Earle, 1985; Arteaga *et al.*, 1994). Changing the level of one variable will change the level of at least one other variable in the experiment as the experiment is subject to a constraint. The constraint in the mixture experimental design is shown as follows:

$$\Sigma_{i=1}^{q} x_i = 1$$

where: q is the number of ingredients in the formulation; x_i represents the non negative proportion of the i^{th} ingredient in the mixture

2.6.3 Echip experimental design program

Echip is a experimental design and analysis computer software which is designed comprehensively for practical implementation (Wheeler *et al.*, 1993). The program offers options in designing experiments, such as mixture design, response surface design, screening design, Taguchi orthogonal arrays and factorial design.

The program covers the basic idea of experimental design and analysis and finds a relationship between a response and one or more control variables. It is structured to address difficulties which often arise in the experimental work, such as developing the relationship between response and variables into an equation and assessing the certainty of the relationship (Wheeler, 1993).

Echip supports four types of design variables: continuous, mixture, categorical and block variables. Continuous variable is an independent variable which its value could be any number defined in a range, while in the mixture variable, the value is described as proportion (Hare, 1974). The sum of the mixture variables is defined as a constraint and causes the variables are interrelated to each other in the experimental design. Categorical variables are described in the terms of distinct categories. The categorical variable is treated as a string character rather than a numeric, thus it can not be interpolated between levels. Block variables are categorical variables which do not interact with other. The block is usually used to separate sets of data taken at different times or under different conditions, for which one suspects there may be an overall shift in the level of the response (Wheeler, 1993). Among those four variables, the continuous and mixture variables are used in this study.

A mixture experimental design is used in this study. In a normal mixture design analysis, all variables follow a constraint which sum to unity. The Echip program has an advantage over standard mixture design analysis because the variables can be freely combined between mixture and non-mixture variables.

PRELIMINARY STUDY OF SNACK DEVELOPMENT

3.1 SNACK MARKET SITUATION

3.1.1 Trend of snack market in the world

The definition of snack food varies depending on the source, for instance the Oxford dictionary (1988) defines snack as a small, casual or very light meal. Willhoft (1990) defined snack food as an impulse purchase food. Booth (1990) considers that a snack food is normally recognized from its size, nature and the fact that it is usually taken quite informally and frequently without implements. Although snack foods vary largely between regions, the categorization of snack is fairly well defined in the cultures in which it is consumed and is clearly recognized as a snack by the consumers.

The snack market could globally be characterized as that of indulgence foods, i.e. foods which are purchased impulsively. However it has been recognised recently that a snack could substitute a meal. As shown in Figure 3.1, countries such as the United States (USA), United Kingdom (UK) and Australia have a higher consumption of snacks than others. Among Asian countries, in 1993 Japan had the highest snack consumption (US $ 15 per capita) and this figure is expected to increase as the snack market is still in the developing stage.

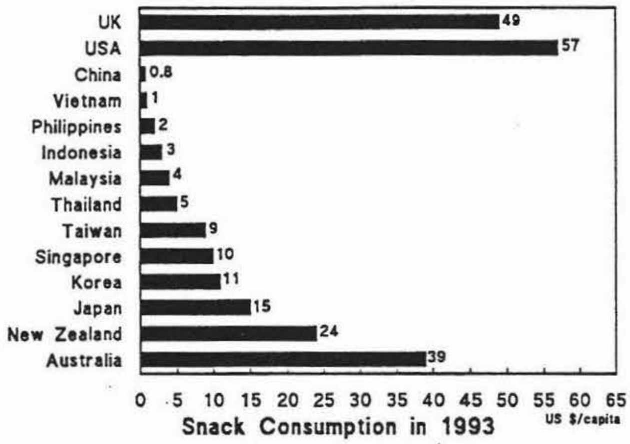

Figure 3.1 Snack consumption per capita and per year in various countries. 1993 (Source: Quest International)

A snack product has a life cycle in the market place. As shown in Figure 3.2, in more developed markets, such as USA, New Zealand (NZ) and Australia, the market has reached maturity. In 1993, Vietnam and China had markets defined as young with a large potential for growth while Indonesia was seen as developing.

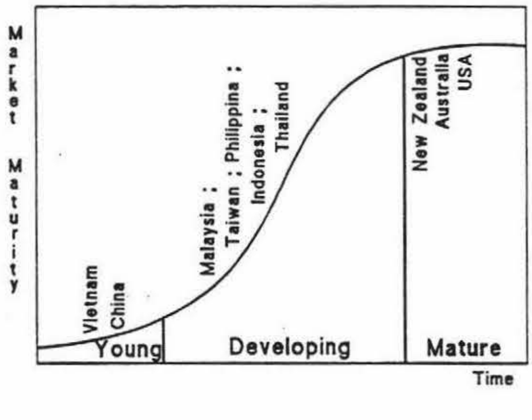

Figure 3.2 Stages of maturity for snack food markets in several countries in 1993 (Source: Quest International)

Indonesians spent about US $ 3 per capita in snacks in 1993. This figure is relatively low, compared to other South East Asian countries, such as Singapore, Thailand and Malaysia. However, this snack market is growing fast as the consumer buying capacity and product awareness is dramatically increasing. The Indonesian snack retail sales in 1995 was US $ 200 million and it is predicted that by the year 2000 the snack market retail sales would reach about US $ 700 million (Anonymous, 1995[a]).

The market for savory/ extruded snacks in the Asia Pacific region has exhibited the most dynamic potential growth in the world. This fact encouraged global snack players, such as United Biscuits and Fritolay (PepsiCo Foods International) to make major investments in the region over the recent years. In addition, Asia's biggest snack food suppliers, such as Calbee from Japan, have also set up their business across the region (Nuboer, 1996, Personal communication).

It has been recognised that consumer satisfaction and consumption motivation are the most important factors that could lead to the product success in the market (Anonymous, 1995[a]). Consumer satisfaction for a snack is normally associated with the product quality and the fulfilment of consumer expectation. However, consumer motivation for purchasing the snack is more loosely defined. It can depend on the motivation for consuming a snack such as boredom, availability of the product and hunger (Anonymous, 1995[a]).

Snack food consumer research conducted by Quest International (1995) in several countries indicated that snack consumption was motivated by several reasons which include hunger, product availability, lack of time for cooking or eating, boredom, indulgence, food eaten during a break, as a reward, convenience, laziness and impulse (Anonymous, 1995[a]). However the main motivation for snack consumption varied among countries. For example, lack of cooking and eating time is the main reason for eating snacks in United Kingdom, while in Australia and New Zealand, hunger and availability are the main reasons for snack consumption. In Asian countries such as Hong Kong and Taiwan, indulgence, boredom and availability cause people to consume snacks. In Singapore, a snack is mostly eaten during a break in work. The snack market in China is relatively new and is developing rapidly. The consumers there eat snacks as an indulgence and impulse food. The western type snack, such as potato chips and extruded snacks have been recently available in the China market, thus encouraging the consumers to purchase new products.

There is no data available about snack consumption motivation in Indonesia and a consumer research was necessary for this project. The situation of the snack market in Indonesia is discussed in Section 3.1.2 and the consumer study carried out in this project for an extruded snack is discussed in Section 3.2.

3.1.2 Snack market in Indonesia

Indonesia has a population of 180 million with sixty percent of its inhabitants living in Java island. In a recent survey (Survey Research Indonesia, 1994), it has been reported that in Indonesia, 25 millions of persons belong to the middle class category who spent over Rp. 400,000.00 per month (NZ$ 1 = Rp.1477)(Anonymous, 1995[b]). This number is growing rapidly and will affect the consumer demand in food and beverage.

The consumers demand towards food and beverages has been changing rapidly in the last decade (Anonymous, 1995[b]). The food preference has slowly moved from the traditional types of food to the western types. This change in food preference has been significant within the Indonesia's growing middle class in where there exists a tendency to equate western with being modern (Earle, 1994). This situation indicates Indonesia is developing as a new potential mass market for western food products.

The snack market is still developing in Indonesia. It was estimated to be worth US \$ 260 million a year in 1993 with local traditional snacks predominantly in demand (Anonymous, 1995[b]). Unfortunately, detailed published statistics is not available.

The snack products consumed in Indonesia could be classified into two types; traditional and modern snacks (Anonymous, 1995[b]; Hawkes, 1995, personal communication). Traditional snacks are ethnic foods normally eaten between meals. Examples of traditional snacks are preserved fruits (such as banana chips/*keripik pisang*, mangoes, papayas); seafood based crackers (such as fish crackers/*kerupuk ikan*, prawn crackers/*kerupuk udang*); nuts and generic local snacks (such as *melinjo* nuts, *keripik*). Modern snacks are more related to the western style, such as potato chips and extruded snacks. In addition to modern snacks, several traditional snacks, such as *melinjo* nuts, shrimp crackers are packed in modern metalized polymer packaging and sold aside western snacks (Hawkes, 1995, personal communication). Traditional snacks are normally packed in plastic or paper bags and have shorter shelf life.

The dominance of traditional snacks makes difficult to define the market share. There are three main snack manufacturers in Indonesia: PT Indocipta pangan makmur, PT. Rosa Murni Utama and PT Pacific International which hold the *Chiki, Taro*, and *Smax* brand, respectively (Anonymous, 1992). In addition Blue Bird Foods NZ has invested NZ \$ 20 million over a five year period to produce western-style and ethnic snack products in a joint venture with Indonesian companies, under the name of PT Smartindo Blue Bird Snacks (Anonymous, 1994). Many small scale snack industries (such as PT Siantar Top Industri, PT Cipta Rasa Primatama and PT Madusari) also play important roles in their regional markets. These regional companies often manufacture snack products of lower cost for a lower income group.

The dominance of traditional snacks is however declining, due to better marketing strategies, particularly in brand and product positioning, practised by western joint venture commercial snack companies, such as PT Indopangan makmur/Indofood-Frito Lay and PT Smartindo Blue Bird Snacks. Mintel Market Research in Australia considers that product and brand positioning in the snack food market is of paramount importance for suppliers who need to establish a clear identity for their products (Anonymous, 1993).

A survey carried out in Surabaya, Indonesia in 1995 showed Indofood Fritolay was the leader in manufactured extruded snacks and potato chips. A list of extruded snacks available in Surabaya is shown in Table 3.1. Table 3.2 shows modern snack products classified according to brand, flavour, suppliers, size and consumer price. Some of these commercial sample specimens are shown in Figure 3.3.

Table 3.1 Extruded snack available in the Surabaya market

Brand	Flavour	Packaging-Sachets (g)	Availability in March/April 1995		
			Open market (out of 1 market)	Supermarket (out of 6 shops)	Dairy shops (out of 4 shops)
Chiki snack ball	Cheese	18	1	5	4
	Chicken	18	1	6	4
	Chocolate	18	1	4	4
Chiki snack-nets	Mexican steak	16	1	5	3
	Barbecue	16	1	3	2
Potato sticks-Chiki snack	Chicken salsa	18	1	4	4
	Soy sauce	18	1	4	3
	Cheese burger	18	1	4	4
Cheetos	Roasted corn	25/55	1	6	4
	American cheese	25/55	1	5	4
	Roasted chicken	25/55	1	6	4
Trampito corn snack	Original corn	18	1	4	2
	Cheese nacho	18	1	4	2
Jetz	Mamamia spicy chicken	20	1	6	4
	Chocolate Fiesta	35	1	5	3
	Fantastic caramel	35	1	5	3
	Paprika great	20	1	6	4
Chiro	Paprika	28	1	5	1
	Corn	28	1	5	1
Double decker	Chicken	18	1	1	3
	Barbecue	18	-	1	2
	Prawn	18	-	2	-
Chikita	Meaty	14	-	5	1
	Vegetable	12	-	5	1
Tato	Chicken-barbecue	15	1	3	-
Taro snacks	Sea weed	18/40	1	5	3
	Yakitori	18	1	5	2
	Teriyaki	18	1	4	1
	Cheese	18/40	1	4	3
	Potato barbecue	18	1	4	2
	Chicken	18/40	1	4	3
Taro potato snack	Soy sauce	20	-	1	1
	Fried chicken	20	-	1	1
Taro corn chips	Grilled beef	20	-	1	1
Taro rice chips	Grilled beef	20	-	1	1

Cont...

Table 3.1 (Cont.) Extruded snack available in the Surabaya market

Brand	Flavour	Packaging-Sachets (g)	Availability in March/April 1995		
			Open market (out of 1 market)	Supermarket (out of 6 shops)	Dairy shops (out of 4 shops)
Serena rice cracker	Cuttle fish	20	-	2	1
	Chicken	20	-	2	1
Potato tubes	Chicken steak	16	1	4	3
	Chicken barbecue	16	1	4	3
Smax rice crackers	Pizza	18	-	4	3
	Cuttle fish	18	-	4	3
	Cheese	18	-	4	3
UFO snack	Tomato barbecue	18	1	1	-
Serena	Corn	50	-	3	1
Potato Stick	Fried chicken	14	1	1	1
Ben-ben	Sesame-chocolate	24	-	1	3
	Banana-chocolate	24	-	1	3
Master pauw	Dried chicken	20	-	1	-
Happy tos	Tortilla chips	25/175	-	6	3
Ozzy	Tomato shrimp	20/40	-	-	2
	Sayur pedas	20/40	-	2	-
	Barbecue corn	20/40	-	2	-
Bigun	Curry	18/100	-	2	-
	Chicken	18/100	-	2	-
	Barbecue	18/100	-	2	-
	Cheese	18/100	-	2	-
Twistko	Barbecue corn	25	1	2	3
Gizanda	Cheese	20	-	1	-

Table 3.2 Modern snacks available in Surabaya. Classified according to brand, flavour, suppliers, size and consumer price. December 1995

Brand	Flavour	Company based on the package information	Sachets (g)	Consumer Price (Rp.)
Chiki snack ball	Cheese	Indofood & Frito-lay;	18	300
	Chicken	Semarang	18	300
	Chocolate		18	300
Chiki snack-nets	Mexican steak	Indofood & Frito-lay;	16	300
	barbecue	Semarang	16	300
Potato sticks-	Chicken salsa	Indofood & Frito-lay;	18	300
Chiki snack	Soy sauce	Semarang	18	300
	Cheese burger		18	300
Cheetos	Roasted corn	Indofood & Frito-lay;	25	375
	American cheese	Semarang	25	375
	Roasted chicken		25	375
Trampito corn	Original corn	Indofood & Frito-lay;	18	400
snack	Cheese nacho	Semarang	18	400
Jetz	Mamamia spicy-chicken	Indofood & Frito-lay;	20	350
	Chocolate	Semarang	35	350
	Caramel		35	350
	Paprika		20	350
Chikita	Meaty	Indofood & Frito-lay;	14	250
	Vegetable	Semarang	12	250
Chiro	Paprika	PT Rasa Murni Utama;	28	350
	Corn	Bogor	28	350
Taro snacks	Sea weed	PT Rasa Murni Utama;	18/40	250/425
	Yakitori	Bogor	18	250
	Teriyaki		18	250
	Cheese		18/40	250/425
	Potato barbecue		18	250
	Chicken		18/40	250/425
Taro potato	Soy sauce	PT Rasa Murni Utama;	20	400
snack	Fried chicken	Bogor	20	400
Taro corn chips	Grilled beef	PT Rasa Murni Utama; Bogor	20	265
Taro rice chips	Grilled beef	PT Rasa Murni Utama; Bogor	20	265

NZ $ 1 = Rp. 1477.00

Cont...

Table 3.2 (Cont.) Modern snacks available in Surabaya. Classified according to brand, flavour, suppliers, size and consumer price. December 1995

Brand	Flavour	Company based on the package information	Sachets (g)	Consumer Price (Rp.)
Serena	Corn	PT Nissin Biscuit Indonesia, Ungaran	50	550
Serena rice cracker	Cuttle fish	PT Nissin Biscuit Indonesia, Ungaran	20	250
	Chicken		20	250
Potato tubes	Chicken steak	PT Sumido Food, Surabaya	16	200
	Chicken- barbecue		16	200
Double decker	Chicken	PT Pacific Food	18	225
	Barbecue		18	225
	Prawn		18	225
Smax rice crackers	Pizza	PT Pacific Food	18	250
	Cuttle fish		18	250
	Cheese		18	250
UFO snack	Tomato barbecue	PT Siantar Top Industri	18	275
Tato	Chicken barbecue	PT Siantar Top Industri	15	100
Potato Stick	Fried chicken	PT Siantar Top Industri	14	110
Happy tos	Tortilla chips	SA-products	25	150
Ben-ben	Sesame-chocolate	PT Gizi Prosana, Jakarta	24	200
	Banana-chocolate		24	200
Master pauw	Dried chicken	PT Cipta rasa PrimatamaJakarta	20	300
Bigun	Curry	PT Smartindo Blue Bird snacks	18	350
	Chicken		18	350
	Barbecue		18	350
	Cheese		18	350
Ozzy	Tomato shrimp	PT Smartindo Blue Bird snacks	20	350
	Sayur pedas		20	350
	Barbecue corn		20	350
Twistko	Barbecue corn	PT Siantar Top Industri	25	255
Gizanda	Cheese	PT Cipta rasa PrimatamaJakarta	20	300

NZ \$ 1 = Rp. 1477.00

Figure 3.3 Several commercial snack products available in the market

The data reported was obtained in 1995 and might have slightly changed during the course of the project, as several new products and companies have recently appeared in the market. For example only 2 supermarkets were selling the *Bigun* - Smartindo Blue Bird brand product when the research was conducted. Because the product was relatively new when the market information was obtained, the *Bigun* snack product is likely to be more accessible now.

From this preliminary study, it can be concluded that the situation on the Indonesian market could be summarised as:

1) The modern snack market is still in the early developing stage, its growth has significantly been outperformed by the traditional snacks. However, it appears that it will develop rapidly. Product quality, distribution, branding and promotion are significant tools in marketing the snack food. Consumer loyalty is obtained faster when superior high quality products are provided at a better value.
2) Most modern snack foods are targeted at children and teenagers, (5-18 years) whilst the traditional snacks are mainly targeted at teenagers and adults. There is a gap market for modern snack products targeted for adults, who are over 18 years of age. For this reason, adults above the age of 18 were selected as the target consumers in this study.

3.2 CONSUMER STUDY FOR EXPANDED SNACKS

3.2.1 Aim of the consumer study

It is recommended to involve the target market of a product in the early stages of the development process, so the product can be developed simultaneously with the consumers' requirement (Earle, 1985). A product has a higher possibility of success in the market if its attributes meet the consumers' requirements.

In this project a consumer study was conducted as a preliminary stage in the snack development. The objectives of this consumer study were:

- to investigate the participants' attitudes towards corn based extruded snacks which are currently available in the market and towards the concept of the extruded snack being developed.
- to ascertain important attributes considered by the consumers when purchasing and consuming an extruded snack.
- to observe participants' attitude towards ingredients used for the production of the snack food, particularly soy bean.

A focus group discussion was selected for this study. This method has the advantage of being able to collect opinions and generate ideas among participants who in this case are the representatives of the consumers.

3.2.2 Focus group and consumer study evaluation

Focus group discussions were held among Indonesians in Palmerston North, New Zealand. Three discussion groups were set and each group consisted of 6 - 8 people. Overall, 22 persons, i.e. 6 females and 16 males, were involved in this study. All participants were adults over 18 years of age.

The discussions took place in the author's flat and run in an informal atmosphere. As an introduction, a general description of the snack development and the aim of the discussion were described. Each participant was then asked to fill in a questionnaire (Appendix 3.1). This questionnaire was to test the knowledge of the participants to extruded corn snacks. Three types of commercial extruded snack samples were given to each participant as references. These references were Twisties (Bluebird Foods Ltd.,NZ); Cheese Burgers (Griffins Foods Ltd., NZ) and Multigrain crisps (Bluebird Foods Ltd., NZ).

The participants' attitudes toward extruded snacks, particularly in purchase, consumption and preferred raw materials were explored in this discussion. The feedback from a participant was generated and further discussed. At the end of the discussion, another set of questionnaires were distributed to the participants to be answered. This questionnaire was to obtain opinions written individually by each participant after the discussion. Formats of both questionnaires used are shown in Appendix 3.1.

Results of the questionnaires were tabulated and analyzed. The different responses among participants were analyzed using a chi-square (χ^2) distribution test to indicate the significance of the differences. For the ranking preference questions, the results were analyzed using Thurston case V (Green *et al.*, 1988).

3.2.3 Consumer attitude towards an expanded snack

All the participants had consumed extruded corn snacks before. From 22 participants, 9 people consume snacks at least 4 times a month, while 8 people consume 2 - 3 times a month. Table 3.3 shows the frequency of consumption of extruded corn snacks.

Table 3.3 Frequency of consumption of corn extruded snack

Frequency	Participants (people) (%)
More than 4 times a week	1 (4.5)
2 - 4 times a week	6 (27.3)
once a week	2 (9.1)
2 - 3 times a month	8 (36.4)
less than once a month	5 (22.7)
Total column	22 (100)

The participants who consume snack at least once a week were likely to be females. From 6 female participants employed in this study, 5 consume snacks more than twice a week. This can indicate that an adult female may be more likely to consume an extruded snack product than an adult male.

Although corn extruded snacks were consumed, most of the participants were not aware of the technical term "extruded snack". They recognised the extrusion type of snack through the local brand names, such as *Chiki*, *Cheetos* and *Twisties*. Therefore, brand awareness is one of the key success factors in the market. Consumer were more familiar with the product when the brand of the product was mentioned, rather than when the term "extruded snack" was quoted.

Flavour was the most important attribute considered in the purchase or consumption of an extruded snack. Among the flavours used in the extruded snack, chicken, cheese and barbecue flavours had a higher preference with the participants (Table 3.4). This information supports the data obtained from the market study which showed that most of the extruded snacks in the market include these three flavours.

Table 3.4 Types of preferable flavour

Types of flavour	Participants on degree of preference (persons)[1]					Weighted sum
	I	II	III	IV	V	$\Sigma(x.n)$[2]
Chicken	7	6	3	3	-	74
Cheese	4	2	5	3	1	50
Barbecue	2	5	2	3	3	45
Chocolate	3	3	1	-	5	35
Potato	2	2	1	3	2	29
Salsa	2	2	1	2	-	23
Mexican spicy	-	1	-	3	2	12
Soy sauce	1	-	2	-	-	11
Roasted corn	1	-	1	1	-	10
Teriyaki	-	-	2	1	-	8
Paprika	-	-	1	-	2	5
Caramel	-	-	-	1	3	5
Beef	-	-	1	-	-	3
Sea weed	-	-	-	-	2	2
Bacon	-	-	-	-	1	1

Note : [1] Degree of preference (I = the most preferable; V = the least preferable)

[2] x = number of participants on each rank
n = factor for the degree of preference (n = 5 for the most preferable; n = 1 for the least preferable); higher value indicates better preference

3.2.4 Important product attributes of an extruded snack

Product attributes are characteristics which can be recognized by consumers. These attributes will affect consumers buying decision of a particular product. Consumers will purchase a product with attributes that suit their wants and needs. Hence, it is essential to identify the important product attributes of the extruded snack and use them to guide the product development process.

The product attributes become critical to the product's success when a consumer purchases the product or when the product is consumed. The attributes would affect the purchase decision and after eating the product, the attributes would influence the re-purchase decision of the product.

This study investigated the important product attributes of an extruded product from two point of views; (1) when the snack is selected to be purchased and (2) when it is consumed. Several important product attributes were identified by the participants in the focus group discussion. The participants also ranked the degree of importance of each attribute.

3.2.4.1 *Important product attributes considered when purchase an extruded snack*

The important attributes considered when an extruded snack is purchased are listed in Table 3.5, and the attributes ranked in the order of importance are shown in Table 3.6. Data from this part of the study is given in Appendix 3.2.

Table 3.5 Important product attributes when purchase an extruded snack

Important product attributes when purchase an extruded snack:

1. Packaging:
   - Appearance:
     should look attractive (bright colour) and hygiene, give a good protection, showing the picture of the product.
   - Size and shape of the package:
     easy to handle/ to open.
   - Information written on the package include:
     * Ingredients list (to indicate that *halal* raw materials are used; no preservatives)
     * *Halal* stamp
     * Expiry date
     * Flavour
     * Nutritional information
     * Consumer guarantee
2. Accessible
3. Reasonable/affordable price
4. Familiarity with the product
5. Brand
6. Occasion
7. Trend in the market at the moment/advertisement

Table 3.6 Degree of importance on each characteristic when purchase an extruded snack

Product attributes	Degree of importance[1)]	Weighted sum $\Sigma(x.n)$[2)]
Flavour	1	156
Familiarity with the product	2	132
Price	3	119
Ingredients list	4	109
Accessibility	5	109
Package size	6	106
Package appearance	7	96
Brand	8	95
Occasion of consumption	9	68

[1)] 1 = the most important attribute; 9 = the least important attribute
[2)] x = number of participants on each rank
n = factor for the degree of importance
(n = 9 for the most important; n = 1 for the least important)

When a consumer purchases an extruded snack, the product is identified by the package. The information written on the package is an attribute that the consumer considers. This information includes type of flavours, ingredients list, *halal* stamp, expiry date, nutritional information and consumer guarantee (Table 3.5).

As shown in Table 3.6, of this information the type of flavours and ingredients list were given more attention than the others. The written flavour on the package suggests how the product inside will taste. The ingredients list informs the buyers about the raw materials being used and will show them that no unexpected raw materials, such as pork tallow, were added.

Knowledge/familiarity of the product and price were more important than the product appearance (Table 3.6). Participants preferred to buy a snack which they have already known and tasted before rather than a totally new snack product. This attitude can be difficult to overcome when introducing a new type of snack product. However, promotional tools, such as free samples, an in-store promotion and extensive advertising would solve this problem. This situation leads the commercial snack companies in Indonesia to emphasize the marketing strategies on the product pricing and promotion. The promotion through advertising can create new trends in the snack food consumption which would stimulate consumers to buy the western types of snack.

This study clearly shows, what many companies already, know that brand awareness is one of the keys to success in the extruded snack market. Global branding strategy has been extensively promoted by Fritolay - PepsiCo Foods International to the consumers, not only in the United States' market but also elsewhere, including Indonesia. Although the study shows that brand had less degree of importance, most snack consumers in Indonesia understood the product terms, *Chiki* or *Cheetos* better than the term, extruded snack. *Chiki* and *Cheetos* were the leading brands of extruded snacks in the Indonesian market, produced by PT Indofood- Fritolay at the time of this study (1995).

The study shows that brand awareness had lesser degree of importance when compared to the product price (Table 3.6). Participants said that they would prefer to buy an extruded snack with a better/lower price to a similar product with an expensive price. The price of the extruded snack should be reasonable and affordable to the target market which has been estimated in the range of Rp. 250 - 300 for a 18-g package. Thus, cost estimation becomes an important step during product development in this study so that the product would have a better chance at the market success.

Package appearance, such as colour, shape and size was also considered in deciding to purchase an extruded snack. The package appearance catches the consumers' attention and promotes the product as an impulse purchase. They may like the product after they have tasted it.

Occasion of consumption was the least important characteristic when purchasing an extruded snack. The reason is because the target market (Indonesians) eats snacks at any occasion. They may consume the snack during meals (lunch and dinner); leisure time (watching television, listening to music); picnics; while working or studying. However, there is a tendency that snack consumption is higher when a group of people is gathered in a social event (Appendix 3.5).

3.2.4.2 *Important product attributes considered when an extruded snack is consumed*

The important attributes considered when an extruded snack is consumed are listed in Table 3.7. These attributes, ranked by the degree of importance, are given in Table 3.8. Details of participants response during the study regarding snack attributes are shown in Appendix 3.3.

Table 3.7 Important product attributes when an extruded snack is consumed

Important product attributes considered when consume an extruded snack:

1. Taste (salty, spicy and tasty)
2. Flavour
3. Crispy & crunchy
4. Not sticky in the mouth
5. Colour
6. Crumbly when chewing/ not rubbery
7. Not oily
8. Not sticky on the hand while holding the snack
9. Reasonable size & shape (have fun while eating)
10. Indication of using *halal* ingredients (eg. no bacon smell)
11. Not feeling bored after eating
12. No thirsty feeling after eating the snack
13. No nauseous effect after eating/ hygiene

Table 3.8 Product attributes when snack is consumed ranked by the degree of importance

Product attributes	Degree of importance[1]	Weighted sum $\Sigma(x.n)$[2]
Flavour	1	203
Crispiness	2	167
Crunchiness	3	153
Colour	4	128
Uniformity in size	5	125
Uniformity in shape	6	120
Crumbliness	7	103
Product melting in the mouth	8	86
Tooth packing	9	61
Adhesiveness in mass	10	59

[1] 1 = the most important attribute; 10 = the least important attribute
[2] x = number of participants on each rank
n = factor for the degree of importance
(n = 10 for the most important; n = 1 for the least important)

As shown in Table 3.8, the acceptability of an extruded snack is mainly affected by its flavour and texture. Consumers will decide whether the flavour is similar to the flavour specified on the package; for example if the flavour written on the package is chicken, the consumer will expect a snack with a chicken taste and smell. In the discussion, participants described the preferred taste of extruded snacks as spicy, salty and tasty. The flavour also indicate that the product was not made from unpreferrable ingredients. For example corn flavour gives an indication that the product is originally made from corn, while bacon flavour will be directly associated with pork and may be rejected by some consumers, such as muslims.

The tastiness of an extruded snack can be enhanced using enhancers, such as mono-sodium glutamate (MSG), sugar and fat. However, the addition of enhancers may cause undesirable effects, such as feeling thirsty after eating the snack, greasy mouth-feel and a nauseous effect. Mogelonsky (1994) explained that one of the success keys for the snack market relied on the snack taste. The taste should be adapted to the local preference. This strategy was used by Fritolay-PepsiCo Foods International who attempts to expand snack markets and adapts product characteristics to local tastes (Benezra, 1995).

Table 3.8 illustrates that texture was considered by the panellists as one of the most important attributes when an extruded snack is consumed (particularly the degree of crispiness and crunchiness). The sound detected by the consumer when biting or chewing the extruded snack would influence its acceptability. This sound was assumed to have a direct correlation with the product freshness. A snack which produced less sound was considered less crunchy or crispy, and thus was less acceptable. The discussion also showed that the participants did not like snack with a rubbery texture as the extrudate type of snack was considered to have a similar product profile to crackers (*keripik/kerupuk*), such as shrimp crackers. It was found that the consumers could not differentiate between the terms crispiness and crunchiness. In this project, the texture of the snack was defined as the degree of crispiness.

Snack appearance, such as colour, size and shape had an almost similar and lower degree of importance (Appendix 3.3). The size should be reasonable so that the snack can be consumed without much effort. The shape should be attractive so the consumer will enjoy eating it. These appearance attributes were more important than other attributes, such as product melting in the mouth, adhesiveness of mass and tooth packing. Since snack was usually consumed during leisure time or while doing other work, it was possible that these later characteristics were not intensively recognized during consumption. In addition, the participants suggested that the snack or snack flavour powder should not stick on the hand while holding it which would interfere with the other activities they were involved in.

3.2.5 Product concept testing for extruded snack

A product concept is the description of a product with its characteristics and attributes. The aim of product concept testing is to obtain consumer's response to the concept of the product. In this study, product concept testing was utilised to get consumer's response towards the raw materials used and their buying attitude for the extruded snack being developed. The description of the extruded snack concept being developed is shown in Table 3.9.

Table 3.9 Extruded snack product concept

An extruded snack is developed at Massey University. This snack is made from corn, defatted soya bean, tapioca and rice flour. The product will be marketed in Indonesia and has several advantages over other products in the market. The product will have a higher protein content, due to the presence of soya bean. Defatted soya bean is a type of plant protein source, which has a high content of protein, low fat and no cholesterol. Because of the addition of tapioca and rice flour in the snack ingredients, the product will become more crispy and crunchy. In addition, tapioca and rice flour will make the snack expand bigger and become lighter.

3.2.5.1 *Participants' attitudes towards raw materials*

The raw material tested was soya bean. This ingredient contains protein which could improve the nutritional quality of the extruded snack. In addition, soya bean has been widely accepted by the target market as a good plant protein source. However, there was still a doubt as to whether consumers could accept the idea of using the soya bean for an extruded snack.

Table 3.10 shows there is a very positive attitude towards the idea of adding soya bean to the formulation. They liked the idea of consuming a nutritious snack food. Some participants could accept the idea, because they were familiar with eating soya bean and they assumed the snack will taste good. Overall they agreed with the inclusion of soya bean in the extruded snack, as long as it would enhance the nutritional quality and palatability of the snack.

Table 3.10 Preference to include soya bean as an ingredient of an extruded snack

Ingredients	Consumer attitude				Total	
	Yes		No			
	(people)	(%)	(people)	(%)	(people)	(%)
Soya bean	21	(95.5)	1	(4.5)	22	(100)

Participants suggested that the extruded snack may also be made with corn, tapioca, rice flour, wheat flour, potato and flavouring agent (Table 3.11). This suggestion indicated that the consumers were familiar with these ingredients. Tapioca and rice flour are widely used to make snacks, such as kerupuk and crackers in Indonesia. Therefore, the addition of tapioca and rice flour might increase the consumers' acceptability towards the extruded snack. From the participants' comments, the product would be more acceptable if the snack is crispy or crunchy, because of the ingredients added.

3.2.5.2 *Buying attitudes towards product concept*

Most of participants (21 people) would like to buy a snack product for the first try, as long as important product attributes, such as reasonable price, flavour, taste and *halal* stamp are provided. They agreed that the snack concept described in this project appears to be more nutritious than those currently available on the market.

In comparison with the currently eaten snack, 17 participants would buy a new extruded snack concept (Table 3.12). The participants agreed that the new snack would have advantages over the currently eaten product as it would have less calories/fat, would be more nutritious and with a better texture (crispier and crunchier). The currently purchased snacks were pop corn, salted nuts, chiki, cheetos and potato chips. The new product concept was also preferred to chocolate bar, as the chocolate bar usually sticks on the roof of the mouth and teeth. Compared to multigrain crisp snacks, one participant preferred the new product concept as it may have a softer texture and more attractive shape.

Table 3.12 Willingness to buy the new product

Willingness to buy	Attitudes				Total	
	Yes		No		(people)	(%)
	(people)	(%)	(people)	(%)		
For a try	21	(95.5)	1	(4.5)	22	(100)
As preference to the currently eaten snack	17	(77.3)	5	(22.7)	22	(100)

df = 2, χ^2 = 3.09 (P=0.49)

Table 3.11 Preference of samples and raw materials estimated by the participants

Types of snack	Total participants' preference out of 22 people	Raw materials		Comments
		Consumer suggestion	Actual ingredient list on package	
Twisties - Bluebird	20	Corn, tapioca, rice flour, wheat flour, salt, fat, cheese flavour	Corn, vegetable oil, cheese powder, emulsifier (471), colour (160e)	The crumbs of product leave a sticky feeling on the hand
Cheeseburger - ETA	21	Corn, tapioca, rice flour, wheat flour, salt, pepper, cheese flavour, vinegar	Corn, rice flour, vegetable oils, anti-oxidants (319, 321), cheese powders, burger flavour	Nice flavour (cheeseburger) & preferred crunchiness/softness
Multigrain - Bluebird	19	Corn, wheat flour, sweet potato flour, rice flour, potato, sugar, tapioca, sago, cheese, vinegar	Corn, vegetable oil, whole wheat, wheat flour, starch, brown sugar, salsa flavour, oat flavour, barley flavour, rice flour, salt, emulsifier (E471)	Nice flavour (salsa), the shape is not attractive, the texture is too hard. However, some participants suggest this hard texture gives a satisfied eating feeling

3.2.5.2 *Buying attitudes towards product concept*

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df = 2, χ^2 = 3.09 (P=0.49)

MATERIALS AND METHODS

4.1 MATERIALS

4.1.1 Raw materials

The ingredients used for the snack base formulation trials were: corn grits, defatted soya flour, rice flour, tapioca flour and baking soda. Corn grits (variety 3162) was supplied by NZ Seed Bank. More than 60 % of the grits had a particle size range of 300 µm - 425 µm. Defatted soya flour was obtained from Cargill, Inc-NZ. Rice flour (Cock brand-Thailand), tapioca flour (Bangkok elephant-Thailand) and baking soda were obtained from Davis Trading, Co-NZ. Both rice and tapioca flours were vacuum packed in plastic bags of 400 g and 454 g, respectively.

4.1.2 Flavour ingredients

The snack was flavoured by coating the base with a flavour powder. The flavour powders were supplied by six commercial companies: Quest International, NZ Ltd.; Bush Boake Allen, NZ Ltd.; Haarmann & Reimer, Bayer NZ Ltd. and NZ Dairy Board, NZ.

Vegetable oil supplied by Davis Trading, Co. was used as the coating medium. In addition, other ingredients, such as whey protein concentrate powder, salt, castor sugar and colouring agent (tartrazine and sunset yellow) were used to improve the product palatability. The whey protein concentrate was supplied by the NZ Dairy Board (NZ), while salt and castor sugar were obtained from Davis Trading, Co. (NZ). The colouring agents, tartrazine and sunset yellow were obtained from Pointing Ltd. (NZ) as laboratory samples.

4.1.3 Ingredient mixture preparation

Ingredient proportions were prepared followed formulations based on the experimental design. Each batch of 5 kg ingredient compositions were mixed using a Hobart mixer at the speed of 2 for 5 minutes. The mixture was prepared approximately 5 hours before manufacture.

4.1.4 Storage of extrudates before analysis

The finished products were packed in polypropylene bags and heat sealed. The samples were stored at room temperature in a dark place. The samples were analyzed within 1 week after their manufacture. For sensory evaluation, the samples were tested within 2-3 weeks after manufacture.

4.2 EXTRUDER OPERATION

Due to the availability in the Department of Food Technology, Massey University, most of the snack development was done on a twin screw extruder (Clextral BC-21, France). A set of trials were also run on a single screw extruder (Lalesse Universal Single Screw Extruder, Netherlands) at the Department of Food Science and Technology, Western Sydney University, Australia.

4.2.1 Twin screw extruder

The twin screw extruder used in this project was a corotating intermeshing extruder with smooth barrel walls and short barrel length (400 mm). It has four temperature zones which can be independently controlled. For expanded products the temperature setting on zone 4 has a large effect on the product expansion. The screw root diameter is constant and different screw configurations can be used depending on the product to be manufactured. Different screw elements are used to carry out operations, such as mixing, compression and shear.

In twin screw extrusion, different process conditions can be obtained through the setting of a specific screw configuration, temperature profile, feed rate, screw speed and water addition. Pre-conditioning of the raw material is not a necessary step when using twin screw extruders. However, it has been recognised that preconditioning could improve the efficiency of the extrusion process as well as the quality of the final product (Jones, 1995, personal communication). A picture of the twin screw extruder is shown in Figure 4.1.

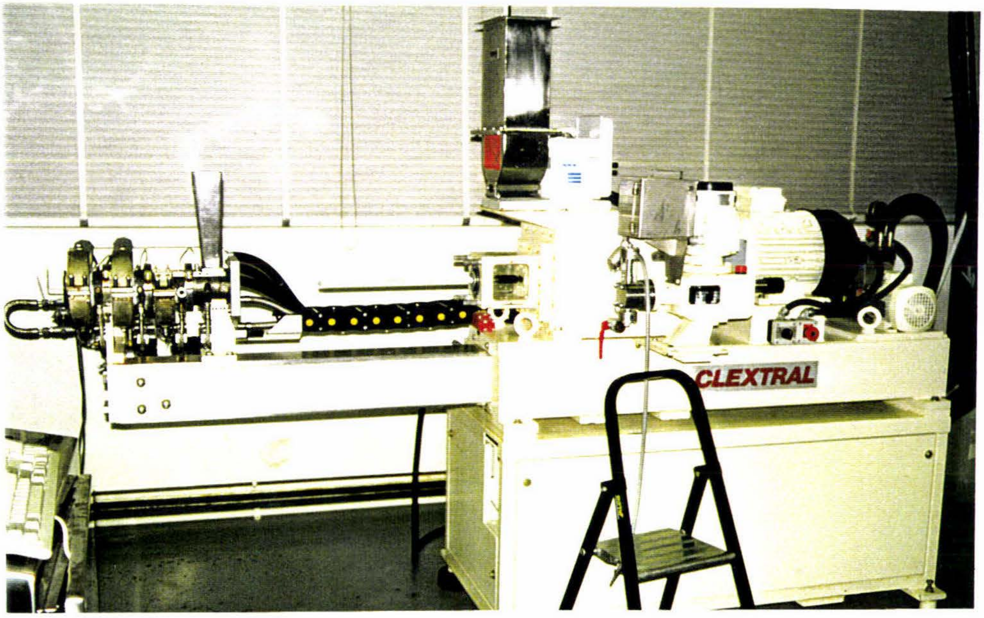


Figure 4.1 Twin screw extruder (Clextral BC-21, France)

The screw configuration selected for the snack development consisted of two screw modules of lengths (25 & 50 mm) and decreasing pitch (13.9, 10.7, 7.6 mm) from feeder to die. A reverse screw element (RSE) was used and placed as indicated in the schematic diagram of the screw configuration shown in Figure 4.2. A die piece with a diameter of 3 mm was placed at the end of the screw barrel.

Extrusion operational variables and proportions of raw materials used were selected based on preliminary production trials (Appendix 4.1). The operational variables studied were screw speed (300-330 rpm), water addition (0.15-0.2 L/hr) and temperature in zone 4 (140-160°C).

The extruder feed rate was set constant at 4.43 ± 0.12 kg/hr. Constant temperatures were also set for zones 1, 2 and 3 at 40°C, 80°C and 115°C, respectively.

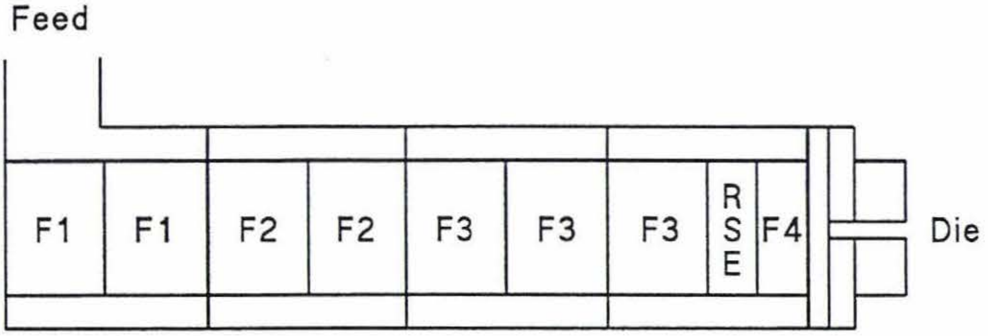


Figure 4.2 Schematic diagram of the screw configuration used in the snack development; F = forward screw element; F1 (pitch = 13.9 mm, length = 50 mm), F2 (pitch = 10.7 mm, length = 50 mm), F3 (pitch = 7.6 mm, length = 50 mm), RSE (length = 25 mm), F4 (pitch = 7.6 mm, length = 25 mm)

4.2.2 Single screw extruder

In order to establish a comparison between the single and twin screw extruder operations for the manufacture of snacks, a single screw extruder (Lalesse, Netherlands) was also used during this project.

This single screw extruder has a short barrel length (approximately 665 mm) and a fixed screw configuration. The screw root has an increasing diameter and the barrel has 2 controlled temperature zones: the feeding and die zones. The process variables can be adjusted through the control of the feed rate, screw speed and zone temperatures. As with most of single screw extrusion processes a preconditioner was used to control the feed moisture. A picture of the Lalesse single screw extruder used in this research is shown in Figure 4.3.

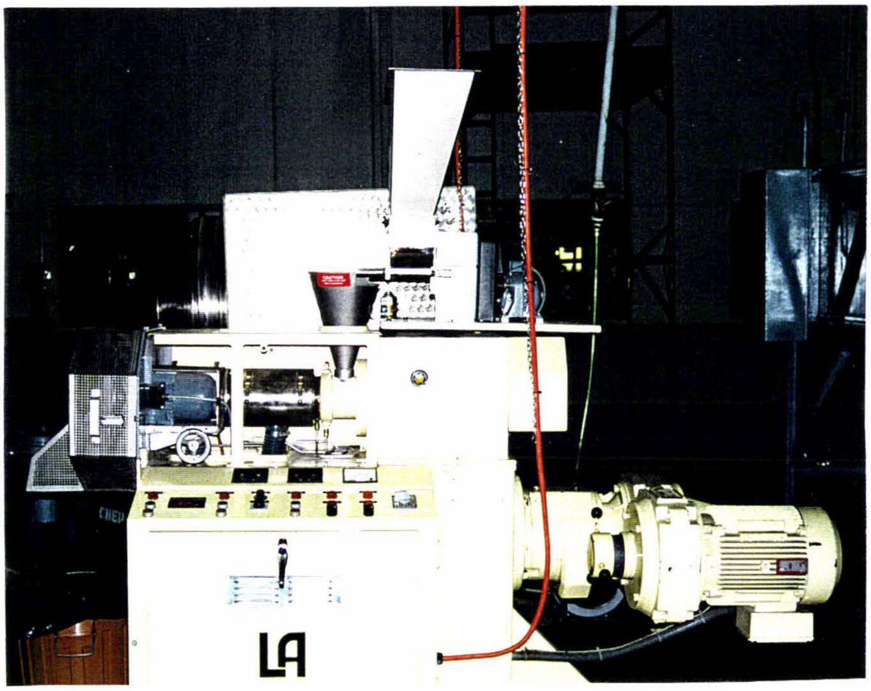


Figure 4.3 Lalesse universal single screw extruder (87-780)

Trials on the single screw extruder were run at constant screw speed and high temperatures. The temperature for zone 1 was kept at 80°C, while for the zone 2 was 170°C. The screw speed was set to 860 rpm to produce enough shear. The feed rate was adjusted to 10 - 17.9 kg/hr. A die with a diameter of 4 mm was used in these trials.

Preconditioning was applied to the ingredients mixture to set the moisture content levels in the range 15 % - 16 %. To obtain 15 % moisture feed, 170 ml water was mixed into 5 kg mixture ingredients for 5 minutes using a Hobart mixer. A similar procedure was applied to obtain 16% moisture feed, 275 ml water was mixed into 5 kg mixture ingredients. The preconditioning was completed approximately 1 hour before the production trial.

4.3 METHODS

4.3.1 Raw materials

4.3.1.1 *Particle size distribution*

A 200 g sample was placed in a set of sieves which have opening sizes of 850 μm, 600 μm, 425 μm, 300 μm, 150 μm and 75 μm. The sieves were shaken for 20 minutes and the sample retained on each sieve was weighed. Percentages retained on each sieve were calculated based on the total sample weight.

4.3.1.2 *Moisture content*

Analysis of moisture content was based on the oven method.

A 3 g sample was weighed in a dried and tared moisture dish. The sample was dried in a conventional oven at 103°C for 5 hours or until a constant weight was reached (difference in weights between two reading was less than 0.001 g). The weight of the dried sample was noted and the moisture content (on a wet basis) of the sample was calculated, using the following equation:

$$MC = \frac{(W\ sample\ -\ W\ driedsample)}{W\ sample} \times 100\%$$

where:
MC = moisture content (% w/w)
W_{sample} = weight of sample (g)
$W_{dried\ sample}$ = weight of dried sample (g)

4.3.1.3 *Water absorption index and water solubility index*

Water absorption index (WAI) and water solubility index (WSI) analysis were carried out according to Anderson *et al.* (1969). The water absorption index (WAI) measures the amount of gel obtained after the sample is suspended in water at 30°C and centrifuged, while the water solubility index (WSI) measures the amount of solids in the sample that are solubilized during the sample suspension.

A sample weighing 2.5 grams was suspended in 30 ml of distilled water at 30°C for 30 minutes. The mixture was stirred intermittently and then centrifuged at 7500 rpm for 10 minutes. For the water solubility analysis, the supernatant liquid was poured carefully into a moisture dish and evaporated until a constant weight was reached (W_s). The remaining gel (W_{gel}) was weighed to determine the WAI. WAI and WSI were calculated using the following equations:

$$WAI = \frac{W_{gel}}{W_{sample}}$$

$$WSI = \frac{W_s}{W_{sample}} X\ 100\%$$

where:
W_{gel} = weight of gel (g)
W_{sample} = weight of sample (g)
W_s = weight of soluble solids in supernatant (g)

4.3.1.4 *Nitrogen solubility index*

The method described in AOCS Method Ba 11-65 (1973[a]) was used to determine the amount of water soluble protein in the sample. The method measures the total nitrogen dissolved in water, after the sample is suspended and stirred, at a slow rate, in water. The nitrogen solubility index is obtained from the ratio between the water soluble nitrogen value (WSN) and the total nitrogen content of the sample (TN).

Total nitrogen content (TN)

The quantitative determination of total organic nitrogen was based on AOCS Ac 4-41 method (1973[b]). The procedure was slightly modified using a Kjeltec system-1007 Digester & 1026 distilling unit (Tecator Sweden). The method measures nitrogenous compounds present which are assumed as the total organic nitrogen in the protein. During the digestion, the nitrogen is reduced to ammonium (NH_4^+). The NH_4^+ produced was recovered as ammonia and calculated as the total organic nitrogen.

The chemicals used were supplied by BDH chemicals (BDH Ltd, Poole, England), except for the Kjeldhal tablets (Kjeltab, Tecator AB, Sweden).

A sample (1-2 g) was weighed and placed into a Kjeldahl flask. 20 ml of concentrated H_2SO_4 and 2 Kjeldahl tablets were added into the flask. Each tablet contains 3.5 g K_2SO_4 and 0.0035 g Se . The content of the flask was slowly heated up to approximately 420°C and digested until the liquid became clear and colourless. The flask was cooled and 50-60 ml boiled water was added to dissolve the precipitated solid. The liquid was distilled with 25 ml of 4% boric acid in the distilling unit. The collected distillate was then titrated with 0.1 N HCl using a mixed indicator of 0.1% bromo cresol green and 0.1% methyl red. The titration was stopped when the end point, solution turned to a grey-mauve colour, was reached.

A blank determination was also carried out using the same procedure and reagents, but in absence of the sample. Total nitrogen contents of the samples were calculated using the following equation:

$$TN = \frac{(S-B) \times 0.014 \times N \times 100}{W_{sample}}$$

where :
TN = total nitrogen content (%)
S = sample titre (ml)
B = blank titre (ml)
N = normality of HCl (N)
W_{sample} = weight of sample (g)

Water soluble nitrogen (WSN)

A 5 g sample was suspended with 200 ml water at 30°C and stirred at 120 rpm for 120 minutes. The volume of the mixture was made up to 250 ml in a volumetric flask and 1 drop of silicone antifoam was added. The mixture was allowed to stand for 5 - 10 minutes. The solids decanted and 40 ml of clear liquid poured into a centrifuge tube. The tube was centrifuged for 10 minutes at 1500 rpm. The supernatant was filtered through glass wool.

5 ml of clear filtrate was pipetted in a Kjedhal flask and analyzed using the Kjeldahl method (described in section 4.3.1.4. for total nitrogen content) to determine the Water Soluble Nitrogen content (WSN). 2 Kjedhal tablets and 15 ml of concentrated H_2SO_4 were used for the digestion process. The WSN was calculated using the following equation.

$$WSN = \frac{(S - B) \times N \times 0.014 \times 10 \times 100}{W_{sample}}$$

where:
WSN = water soluble nitrogen (%)
S = sample titre (ml)
B = blank titre (ml)
N = normality of HCl (N)
W_{sample} = weight of sample (g)

The Nitrogen Solubility Index (NSI) was calculated as a percentage of the ratio between the Water Soluble Nitrogen value (WSN) and the Total Nitrogen value (TN):

$$NSI = \frac{WSN}{TN} \times 100\%$$

where :
NSI = nitrogen solubility index (%)
WSN = water soluble nitrogen (%)
TN = total nitrogen content (%)

4.3.2 Extrudates

Properties of the extrudates were measured before the sample was flavoured.

4.3.2.1 *Functional properties analysis*

4.3.2.1.1 *Moisture content*

Moisture contents of extrudates were measured using the moisture dish method described in section 4.3.1.2. The extrudate was ground before the analysis.

4.3.2.1.2 *Water absorption index and water solubility index*

Water absorption and water solubility indices were determined using the method described in section 4.3.1.3. Before the analysis, the sample was ground and sieved. The sample particle size was within 300 - 600 μm.

4.3.2.1.3 *Nitrogen solubility index*

A similar method to that of section 4.3.1.4 was carried out to determine the nitrogen solubility index of extrudates. The sample was ground and passed through a 150 μm screen.

4.3.2.1.4 *Glass transition temperature*

The glass transition temperature of the extrudate samples were determined using Differential Scanning Calorimetry (DSC) (Perkin Elmer DSC7). The glass transition temperature (Tg) is defined as the temperature at which the sample change from a glass state to an amorphous state. This change in the structure of the sample is associated with a change in its thermal properties (heat capacity). The change in heat capacity can be measured using a DSC instrument and therefore determine the glass transition temperature.

Two to four mg ground samples were sealed in DSC - aluminium pans (Sample Perkins-Elmer Kit No.0219/0062) using a Perkin Elmer pan-sealer. The sample were heated from 20 to 120°C at a scanning rate of 10°C/min. Tg was determined as the temperature where a change of base line in the heat flow-temperature curve was noted. A typical curve of DSC measurements is illustrated in Figure 4.4. The figure also shows that the transition between the glassy and amorphous state occurs within a range of temperature. For calculation of Tg, the middle point of the range was considered.

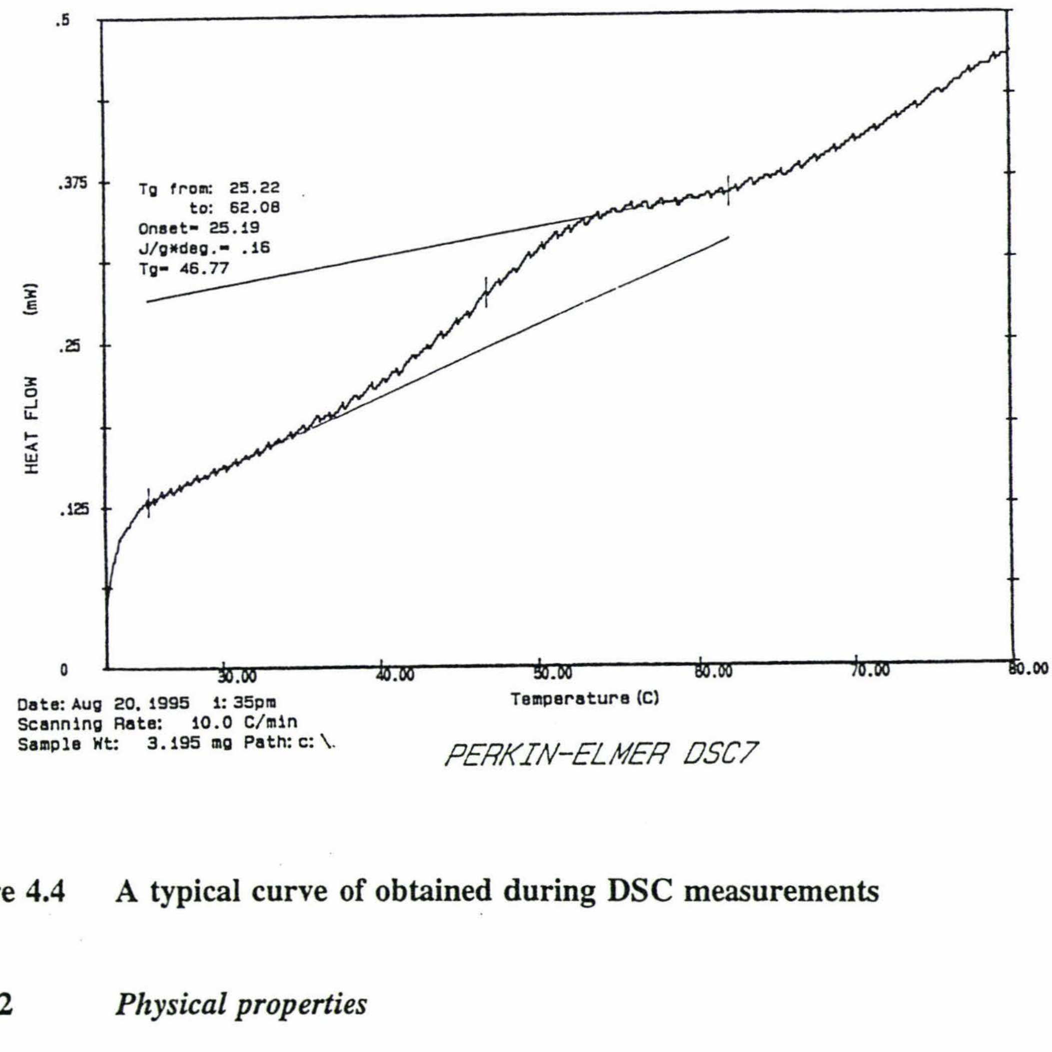


Figure 4.4 A typical curve of obtained during DSC measurements

4.3.2.2 *Physical properties*

The physical properties of the snack base were determined prior to flavouring. The physical properties measured were colour and texture.

4.3.2.2.1 <u>*Colour measurement*</u>

The extrudate colour was assessed by a Hunter L^*, a^*, b^* colour measurement system using a Minolta Chromameter CR-200. The Hunter L^*, a^*, b^* colour represents the degree of hue, where hue is defined as the intensity of a particular type of colour. The lightness or darkness is defined as L^* value. The scale range for L^* is from 0 to 100, where 0 represents a completely non-reflecting black body and 100 represents a completely reflecting white body. a^* refers to the degree of redness/greenness. Its scale range is from +100 to -80, where a positive a^* value ($+a^*$) indicates more degree of redness while a negative a^* value ($-a^*$) indicates more degree of greenness. The degree of yellowness/blueness is defined as b^*. The scale range of b^* are from +70 to -80, where a positive b^* value ($+b^*$) indicates more degree of yellowness while a negative b^* value ($-b^*$) indicates more degree of blueness. In addition, a colour difference parameter (ΔE^*) can be determined from L^*, a^* and b^*.

A petri dish was filled with ground samples (150 - 300 μm) to a depth of 5 mm. The Minolta chromameter CR-200 was calibrated against a standard plate. The petri dish was placed on the colour detector and covered with a black surface. By taking account of the standard values, the colour were calculated as L^*, a^*, b^* and a colour different value (ΔE^*). The ΔE^* is calculated using the following equations:

$$\Delta E^* = ((\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2)^{½}$$

where : $\Delta L^* = L^*\text{standard} - L^*\text{sample}$

$\Delta a^* = a^*\text{standard} - a^*\text{sample}$

$\Delta b^* = b^*\text{standard} - b^*\text{sample}$

4.3.2.2.2 *Texture measurement*

The texture of extrudate samples was measured using an Instron Universal Testing Machine Model 4502. A 5 cm sample was placed on the sample holder (Figure 4.5.). The cross-speed of the Instron machine was set at 50 mm/min. The maximum force required to break the sample (in Newton) was measured as the breaking strength (BS). The hardness of samples were assessed by the value of the breaking strength.

Figure 4.5 Chisel probe for testing extrudate samples

4.4 SENSORY EVALUATION

4.4.1 Panellists

Consumer panellists were selected for the sensory testing in Palmerston North, New Zealand and in Surabaya, Indonesia. All panellists were adults over 18 years of age.

During the development of a product, consumers must be involved, so that the developed product meets the consumers' needs. On the other hand, consumer involvement in the product development can establish several constraints, such as cost and the new product can be judged by some of the potential consumers before its launching time. The number of panellists involved can vary depending on the degree of data accuracy needed. Less panellists are used if a qualitative information or an exploratory market research is investigated. More panellists are required if the developer needs more quantitative data. More panellists involved will give a better picture of the population, in this case the target market.

In this study, the number of panellists varied on each testing, mainly due to nature of each testing procedure used. The number of panellists for the flavour screening, formulation development and final consumer product testing were described in sections 4.4.1.1 - 4.4.1.3, respectively.

4.4.1.1 *Flavour screening*

Twenty flavours were received from commercial flavour companies. These flavours were screened down using consumer preference.

A small group of 3 - 10 people was used for the preliminary screening of flavours. This group was invited to contribute any suggestions on the basic taste perceptions, such as the balance in the flavour intensity, the degree of saltiness and sweetness which were acceptable for the Indonesian consumers, as well as to obtain the flavour acceptable dose level to be applied in the snack.

4.4.1.2 *Formulation development*

For sensory evaluation of a new product, it is not always convenient to use a large number of participants in order to gather data which can be statistically analyzed. It has been stated that a group of 20 - 30 people can provide reliable data to evaluate a product (Meilegard *et al.*, 1987[a]).

In this study groups of 28 to 33 panellists participated in the formulation development and comparison of products manufactured using the different extruders (single and twin screw extrudates). The panellists were Indonesian who have lived in Palmerston North for less than 2 years. Most of them were students at Massey University.

4.4.1.3 *Final consumer test*

A larger number of panellists is required for the final consumer product test. In this study, 147 people participated for the large scale consumer test. Students and staff from the University of Wydia Kartika and University of 17 Agustus in Surabaya (Indonesia) were selected as the panellists for the final product testing.

4.4.2 Testing environment

Most of the sensory evaluation tests were conducted in central locations: Massey University, University of Widya Kartika and University of 17 Agustus. In-house testing was also used for the acceptability test during the snack base formulation.

4.4.3 Line scale acceptability test

A line scale method was carried out to assess the product acceptability. The method measures the intensity of a given stimulus attribute by making a mark on a horizontal line. The marks in the line are converted to numbers by manually measuring the position of each mark from the left hand end, for each scale. The data are then analyzed using statistical methods, such as t-test, ANOVA or regressions (Meilgaard *et al.*, 1987[a]).

A 10 cm line scale was used to evaluate the overall snack base formulation acceptability. The panellists were asked to give a mark on a 10 cm line to indicate their degree of acceptability. Each mark was measured from the left hand end and converted as a ratio of 10. A higher ratio indicated that the product was more acceptable.

4.4.4 Hedonic preference test

A hedonic scale is used to indicate the degree of acceptability of a product. Panellists are presented with a scale which can be five, seven or nine points and are asked to indicate their product acceptance by writing the number that reflects their liking. Table 4.1 shows a seven point verbal hedonic scale. The panellists consume the sample and select the number which best fits their liking of the sample. The data obtained is statistically analyzed using either analysis of variance (ANOVA) or t-test. The assessment using ANOVA is used when the number of samples are more than two, while t-test is used for testing two samples (Meilgaard, *et al.*, 1987[a]). If there is any significant difference detected in ANOVA, then further data analysis is carried out using a multiple comparison test. The most common multiple comparison test used in sensory evaluation is the Least Significant Difference (LSD) or Tukey's Honestly Significant Difference Test. From the test results, consumer preference can be inferred (Meilgaard *et al.*, 1987[a]).

Table 4.1 Seven point verbal hedonic scale

1	=	Like very much
2	=	Like moderately
3	=	Like slightly
4	=	Neither like nor dislike
5	=	Dislike slightly
6	=	Dislike moderately
7	=	Dislike very much

For this research, a seven point verbal hedonic scale was used to evaluate the product preference (Table 4.1). The attributes evaluated in the test included colour, aroma, texture, flavour, overall appearance and overall preference. The data obtained were statistically analyzed using either analysis of variance (ANOVA) or the t-test. The assessment using ANOVA was carried out when the number of samples was more than two, while the t-test was used for testing two samples. When a significant difference was detected with ANOVA, then further data analysis was carried out using a Tukey's Honestly Significant Difference test to find out the product or products with different attributes. The search was, however, oriented to determine the products with higher preference scores.

4.4.5 Ranking test

A ranking test is a test in which three or more samples are evaluated and arranged in order of intensity or degree of some specific attribute (Meilgaard *et al.*, 1987[a]). The rank numbers received by each sample are summed and the resulting sum indicates the overall rank order of the sample. The results can be analyzed using any test of significance, for example the chi-square (χ^2) test.

A ranking test was carried out as a rapid test to obtain an idea about the most preferred snack product. Three to four samples were served and the panellists were asked to rank them. The rank numbers received by each sample were weighed summed. The χ^2 statistical test was carried out to indicate significant differences between samples.

4.4.6 *Just right* scales test

The *just right* scale test is often used to determine reasons for acceptance or rejection of a particular sensory attribute, such as texture. Panellists assess the intensity of a sample attribute, using a just right scale, in comparison to their preconceived idea of the sample (Meilgaard *et al.*, 1987[a]). The panellists indicate their degree of liking of the attribute intensity by writing a number against the appropriate description. Table 4.2 shows an example of a *just right* scale test applied to evaluate product crispiness.

Table 4.2 Example of a *just right* scale

1 =	Much too crispy
2 =	Slightly too crispy
3 =	Just right
4 =	Slightly too little crispiness
5 =	Not crispy enough

To analyze the data, the descriptions are converted to numbers (Table 4.2.) and the percentage of panellists who respond in each number of categories is calculated. A significance level test, such as χ^2 test, ANOVA or t-test can be used to assess a particular product attribute.

In this project a *just right* test was used to assess the crispiness intensity of extrudates produced with the single and twin screw extruders (Chapter 8). The data was analyzed using a t-test.

4.5 CALCULATION OF SPECIFIC MECHANICAL ENERGY

Specific Mechanical Energy (SME) is a process variable commonly used in extrusion to indicate the mechanical work at which the sample is subjected to during the extrusion process. Specific Mechanical Energy is calculated based on equation (1):

$$SME = \frac{T * \omega}{F} \qquad (1)$$

where:
T = torque (N.m)
ω = screw speed or angular viscosity (1/sec)
F = total feed rate (kg/hr)

The total feed rate (F) is calculated as the sum of the ingredients feed rate (F_i) and the water addition (F_w).

$$F = F_i + F_w \qquad (2)$$

For the twin screw extruder using values of screw speed in rpm, the equation becomes

$$SME = \frac{2\pi}{60}\frac{T * S}{F} \qquad (3)$$

where:
S = screw speed (rpm)

For the single screw extruder

$$T = K * A \qquad (4)$$

where:
K = constant

Torque in the single screw extruder was measured as a current so the constant K is used as a conversion factor from Amperes (A) to N.m. Unfortunately, the value of the constant could not be found in the extruder literature information, therefore values of SME affected by this constant will be used for comparison.

$$SME = \frac{2\pi}{60}\frac{K*A*S}{F} \qquad (5)$$

where:

SME	=	specific mechanical energy (W hr/kg) for the single screw extruder SME = ~ W hr/kg
S	=	screw speed (rpm)
F	=	total feed rate (kg/hr)
K	=	constant (N m/A)
A	=	amperage (A)

4.6 COST OPTIMIZATION

During the product formulation, the cost was analyzed and optimized. Linear programming was used to minimize the cost and optimize product formulation. A linear programming package (LP88) was used for the optimization.

A linear programming model comprises three major components: objective function, decision variables and constraints. In this work, the objective function was the cost which was minimized and compared with an acceptable limit of Rp.4000 per kilogram including the flavouring agent (Hawkes, 1995, personal communication). It was assumed that the flavouring agent would cost about 50% of the product cost. Therefore, the maximum acceptable product cost for the snack base was Rp. 2000 per kilogram (about NZ$ 1.35).

Cost of ingredients used in the product formulation

The cost of each ingredient used in the product formulation is shown in Table 4.3. These costs were industrial prices obtained from suppliers either in Indonesia or in New Zealand, but all are applicable to Indonesia.

Table 4.3 Cost of ingredients used in the snack formulation

No.	Items	Cost[1) (Rp./kg)	Sources
	Ingredients for snack base:		
1.	Corn grits	1329.47	NZ Seed Bank, NZ
2.	Defatted soya flour	3520.00	International Food Agencies Ltd., NZ.
3.	Rice flour	1140.00	Brand rose, Indonesia
4.	Tapioca flour	1000.00	Brand obeng, Indonesia
5.	Baking soda	2068.00	David Trading, NZ
	Ingredients for flavour coating:		
6.	Cheese powder - ATCP 1013	7800.00	NZ Dairy Board
7.	Cheese powder - ATCP 1014	11242.00	NZ Dairy Board
8.	Cheese powder - ASP 2001	6457.00	NZ Dairy Board
9.	Cheese powder - A 2003 SS	6413.00	NZ Dairy Board
10.	Cheese & onion - AFP 355	9240.00	NZ Dairy Board
11.	Sour cream & chives - 9110	12554.50	Griffith Laboratories
12.	Chicken flavour base - 7718	21415.50	Haarmann & Reimer
13.	Crispy fried chicken - APO 2656	n.a	Quest International
14.	Chicken saroline - E 4.6264	8492.75	Bush Boake Allen
15.	Mexican chicken 2 - E 5.6064	13588.40	Bush Boake Allen
16.	Barbecue seasoning - 9127	11077.50	Griffith Laboratories
17.	Hot 'n spicy barbecue - E 5.6065	12332.95	Bush Boake Allen
18.	Barbecue saroline - E 5.6000	9157.40	Bush Boake Allen
19.	Barbecue chip saroline - E 4.6150	9157.40	Bush Boake Allen
20.	Cajun - 5492	10339.00	Griffith Laboratories
21.	Curry - 7314	n.a	Haarmann & Reimer
22.	Ethnican - QZ 02346	12554.50	Quest International
23.	Nacho - 9166	14750.50	Griffith Laboratories
24.	Spicy jalapeno seasoning - 9161	12554.50	Griffith Laboratories
25.	Roasted Corn - QZ 02352	25847.50	Quest International
26.	Castor sugar	1500.00	Indonesia
27.	Salt	800.00	Indonesia
28.	Vegetable oil	2000.00	Indonesia
29.	Tartrazine	69419.00	Warner Jankinson, NZ
30.	Sunset yellow	72373.00	Warner Jankinson, NZ

[1) The price is on f.i.s (freight, insurance and storage) Indonesia
NZ$ 1 = Rp.1477 ; US$ 1 = Rp.2200
n.a = not available

The cost of the snack base was calculated from the cost of the ingredients as follows:

Z = 1329.47 (corn) + 3520 (defatted soya flour) + 1140 (rice flour) + 1000 (tapioca flour) + 2068 (baking soda)

This cost was the objective function that the linear programming package minimized. The five basic ingredients used in the cost equation were set as the decision variables (Table 4.4).

Table 4.4 Decision variables in the snack base formulation

Raw materials	Variables
Corn	X_1
Defatted soya flour	X_2
Rice flour	X_3
Tapioca flour	X_4
Baking soda	X_5

Constraints were set for the raw material levels. These levels were obtained from various trials and error preliminary production trials which are fully described in Appendix 4.1. Nine constraints were set. The first constraint is obvious as it related the proportion of each ingredient in the formulation. Constraints 2 - 6 were the lower and upper levels for defatted soya flour (X_2), rice flour (X_3) and tapioca flour (X_4) determined during the preliminary trials. The corn and baking soda were set at constant levels on constraints 7 - 8.

Constraints :

$$
\begin{aligned}
X_1 + \quad X_2 + X_3 + X_4 + X_5 &= 1 && (1)\\
X_2 &\leq 0.28 && (2)\\
X_2 &\geq 0.1 && (3)\\
X_3 &\leq 0.2 && (4)\\
X_3 &\geq 0.02 && (5)\\
X_4 &\leq 0.1 && (6)\\
X_1 &= 0.596 && (7)\\
X_5 &= 0.004 && (8)
\end{aligned}
$$

The constant level for the corn (0.596) was set by a product constraint, i.e. the snack should be made with more than 50% corn. The baking soda level (0.004) was set in a preliminary trial which showed that 0.4% of baking soda improved the extrudates air cell size distribution and their texture (Appendix 4.1).

4.7 DATA PROCESSING METHOD

Four computer programmes were used for data processing during the optimization. These programs were:

- Quattro Pro 5.0 (Borland International, Inc., USA)
- LP88 (Eastern Software Products, Inc., Virginia, USA)
- Echip program 6.04 (ECHIP, Inc., Hockessin, DE, USA)
- Minitab 10.5 (Minitab, Inc., Pennsylvania, USA)
- SAS 6.0 (SAS Institute, Inc. USA)

Data was entered on Quattro Pro spreadsheet before being analyzed further. Quattro Pro was used to calculate means, variances and standard deviations of physical properties and sensory evaluation data. It was also used for analysis of variance (ANOVA) and t-test of the data obtained from the sensory testing.

LP88 was used to minimize the product cost using linear programming.

Echip program 6.04 was used to carry out the experimental design to set the snack base formulations. Echip generated the processing and formulation conditions using a mixture design variable and developed mathematical equation models to fit experimental data.

For the scale type of test, the data was analyzed using Thurstone Case-V (Green, *et al.*, 1988). The ranking test data was analyzed (as a categorized data) using a chi-square (χ^2) distribution test (Bhattacharya & Johnson, 1977).

Minitab 10.5 was used for sample randomization for the sensory evaluation tests and for analysing data of the final product testing, while SAS was used for analysis of variance (ANOVA) and multiple comparison test on the snack base formulation.

STUDY OF PROPERTIES OF THE EXTRUDED SNACK BASE MANUFACTURED USING A TWIN SCREW EXTRUDER

5.1 INTRODUCTION

During the extrusion process, a great deal of interaction exists between the extruder operating conditions and the characteristics of raw materials which affect the properties of the final product. It would be an advantage for a product developer to understand these concepts and build up a knowledge of the key factors involved on the extrusion process and how they affect the product characteristics. For this reason, a study of the effect of operating conditions and raw material characteristics on the functional, physical and sensory properties of extrudates was conducted in this research.

A consumer acceptability test was also conducted to screen optimum basic formulations and process conditions to produce the final snack base which was used in the extruded snack formulation (Chapter 6).

Specific objectives of this study were:

- To investigate the effects of ingredients on the snack properties.
- To investigate the effect of operating conditions, particularly water addition, temperature at zone 4 and cooking time (controlled by the screw speed) on the extrudate functional and physical characteristics.

A mixture design was used in this experiment to provide the different combination of ingredients and process conditions. Raw materials were combined in a range of formulations and extruded under several process conditions, using a twin screw extruder Clextral BC-21. The formulations and process conditions were set by the experimental design described in section 5.3.

5.2 PRELIMINARY PRODUCT COST OPTIMIZATION

As shown in Table 5.1, a linear programming program was used to minimize the product cost. The model was comprised of a cost objective function, a formulation constraint (1) and ingredient level constraints (2) - (8). The formulation constraints were set as explained in section 4.6.

Table 5.1 Model for cost minimization

Objective Function:	Z = 1329.47 (corn) + 3520 (soya flour) + 1140 (rice flour) + 1000 (tapioca flour) + 2068 (baking soda)	
Formulation constraint:	Corn+ soya flour + rice + tapioca + baking soda = 1	(1)
Ingredient level constraint:	Soya flour ≤ 0.28	(2)
	Soya flour ≥ 0.1	(3)
	Rice ≤ 0.2	(4)
	Rice ≥ 0.02	(5)
	Tapioca ≤ 0.1	(6)
	Corn $= 0.596$	(7)
	Baking soda $= 0.004$	(8)

A feasible result was obtained from the linear programming program and is given in Table 5.2. The snack base cost was lower than the maximum expected cost (Rp. 2000/kg).

Table 5.2 Solution on cost minimization model using linear programming

Raw materials	Solution
Corn	0.596
Defatted soya flour	0.1
Rice flour	0.2
Tapioca flour	0.1
Baking soda	0.004
Snack base cost (Rp./kg)	1480.64
Cost feasibility	Feasible

The formulation obtained (Table 5.2) was used as a guide in setting the experimental design constraints (section 5.3) as the model which provided a product with the minimum cost but not necessarily an optimum product in other areas, e.g. consumer acceptability.

5.3 EXPERIMENTAL DESIGN FOR THE EXTRUDED SNACK BASE FORMULATION

A constrained mixture design was used in this study. The design was obtained from the Echip program version 6.0. (ECHIP corp., USA).

Continuous variable is used in Echip experimental design as a term to describe an independent variable with any value that could be defined in a given range. Mixture variable, on the other hand, is a variable, defined as a proportion. Therefore the total sum of mixture variables should add up to 1 or 100%. This condition constitutes one of the constraints of the problem. In this study the continuous variables were the processing conditions, and the mixture variables were the proportion of the raw materials used in the formulation.

To eliminate an excessive number of experiments, variables which have larger effects on the snack properties were selected from preliminary experiments (detailed in Appendix 4.1).

Raw materials used to produce the snack base were corn meal, defatted soya flour, rice flour, tapioca flour and baking soda. Corn and baking soda were kept at a fixed level and defatted soya flour, rice flour and tapioca flour were varied according to the experimental design described in Table 5.3. Defatted soya flour, rice flour and tapioca flour were defined as the mixture variables in this experimental design and their upper and lower limit were set with the ingredient level constraints obtained in the preliminary product costing (Table 5.1).

Table 5.3 Raw materials used in the study

Raw materials	Proportion (%)	
Fixed level :		
Corn meal	59.6	
Baking soda	0.4	
	Sub total	60
Mixture variables :	Range	
Defatted soya flour	10 - 28	
Rice flour	2 - 20	
Tapioca flour	0 - 10	
	Sub total	40
Total		100

As mentioned before in a constrained mixture design, the sum of mixture variables ratio should equal to one. Thus, one of the constraint for this design is defined as:

Constraint: ***Defatted soya flour ratio + rice flour ratio + tapioca flour ratio = 1***

The proportion of the raw material variables (mixture variables) was transformed into ratios (based in a total of 40%) as shown in Table 5.4. The complete list of variables used in the experimental design is shown in Table 5.5.

Table 5.4 Transformation of mixture variables percentages into ratios

Mixture variables	(%)	Ratio
Defatted soya flour	10 - 28	0.25 - 0.7
Rice flour	2 - 20	0.05 - 0.5
Tapioca flour	0 - 10	0 - 0.25
Total	40	1

The process conditions (continuous variables) included screw speed, water addition and temperature at the extruder fourth zone.

Table 5.5 Variables used in the experimental design

Type of variables	Variable	Value
Mixture variable	Defatted soya flour	0.25 - 0.7
	Rice flour	0.05 - 0.5
	Tapioca flour	0 - 0.25
Continuous variable	Screw speed	300 - 330 rpm
	Water addition	0.15 - 0.2 kg/hr
	Temperature at 4th zone (T4)	140 - 160°C
Fixed conditions	Corn meal	59.6 %
	Baking soda	0.4 %
	Temperature at 1th zone (T1)	40°C
	Temperature at 2th zone (T2)	80°C
	Temperature at 3th zone (T3)	115°C
	Feed rate	0.55 rpm ≈ (4.31 - 4.55 kg/hr)

A total of 31 random trials were carried out in this design which consisted of 26 different trials and 5 replicates of the first five treatments. Echip program replicates the first five treatments in the design to determine the standard error among trials. The details of the 31 trials are shown in Appendix 5.1.

Properties of samples obtained from the trials were determined and the results were analyzed using the Echip program to determine the variables that produce significant effects on the product characteristics and the equation models. Quadratic equations were used for the models.

5.4 ANALYSIS OF RAW MATERIALS AND EXTRUDATE

5.4.1 Raw materials

Ingredients particle size distribution and feed moisture are important properties to control in the extrusion process. Bigger particle size could affect the degree of cooking time, while finer particle size reduced the shear produced. The particle size also affects the extrusion residence time while the feed moisture affect the viscosity of the extrudate melt. Therefore the particle size distribution and ingredients moisture content were measured as described in sections 4.3.1.1 and 4.3.1.2, respectively. Appendix 5.2 shows the particle size distribution of the raw material mixtures. More than 90 % of the particle size on each formulation was less than 425μm, which 30% of those had a size less than 75μm.

In order to determine the effect of processing on the functional properties of raw materials, water absorption index (WAI), water solubility index (WSI) and nitrogen solubility index (NSI) of raw materials of each formulation mixture were also measured following the methods described in sections 4.3.1.3 and 4.3.1.4. The complete set of measured results, including the moisture content (MC) are given in Appendix 5.3.

5.4.2 Extrudates

Extrudates produced in each trial were analyzed. Their functional and physical properties and consumer acceptability were determined. The specific mechanical energy applied in each trial was also calculated.

5.4.2.1 *Functional properties analysis*

In order to obtain information about the functional properties of the extrudates and how they are affected by the ingredients and the extrusion process. Moisture content (MC), water absorption index (WAI), water soluble index (WSI), nitrogen solubility index (NSI) and glass transition temperature (Tg) of each sample were determined in duplicate. Methods are described in section 4.3.2.1.

5.4.2.2 *Physical properties analysis*

The samples were analyzed for texture and colour. The texture was determined as the breaking strength (BS) (the stress to produce breakage of the sample) using an Instron Universal Testing Machine. Six replicates were tested for each sample. The colour measurements were obtained using a Minolta chromameter CR-200 as values of L^*, a^*, b^* and ΔE^*. Three replicates were taken for each sample. Methods to determine the texture and colour are described in sections 4.3.2.2.1 and 4.3.2.2.2, respectively.

5.4.2.3 *Acceptability test*

A consumer test was used to evaluate the samples produced during the trials. The samples with the highest acceptability were selected as the snack base for further development.

As the number of samples (31 samples) was excessive for a sensory evaluation test, the samples were divided into 6 groups/sections. Each group/section contained 5 to 6 samples.

In-house consumer testing was selected in this study. This testing allowed consumers to be more flexible with the testing time. Furthermore, when the test was run, it was almost examination time at Massey University and it was inconvenient to run a laboratory test for all 6 groups/sections at a short period of time. The panellists would not have been willing to come frequently to the laboratory to carry out the testing, as that would have interrupted their work.

Thirty people volunteered to participate in this test as panellists. The samples were sent to their houses. Each panellist received one large bag containing 6 sample groups. Every group consisted of 5 to 6 types of snack products with enclosed information and a questionnaire sheet. A 10 cm line scaling test was used in this test (described in section 4.4.3). On the sample delivery, the testing instructions were briefly explained.

The information and questionnaire sheet are shown in Appendix 5.4. A picture of the samples given to panellists is shown in Figure 5.1.

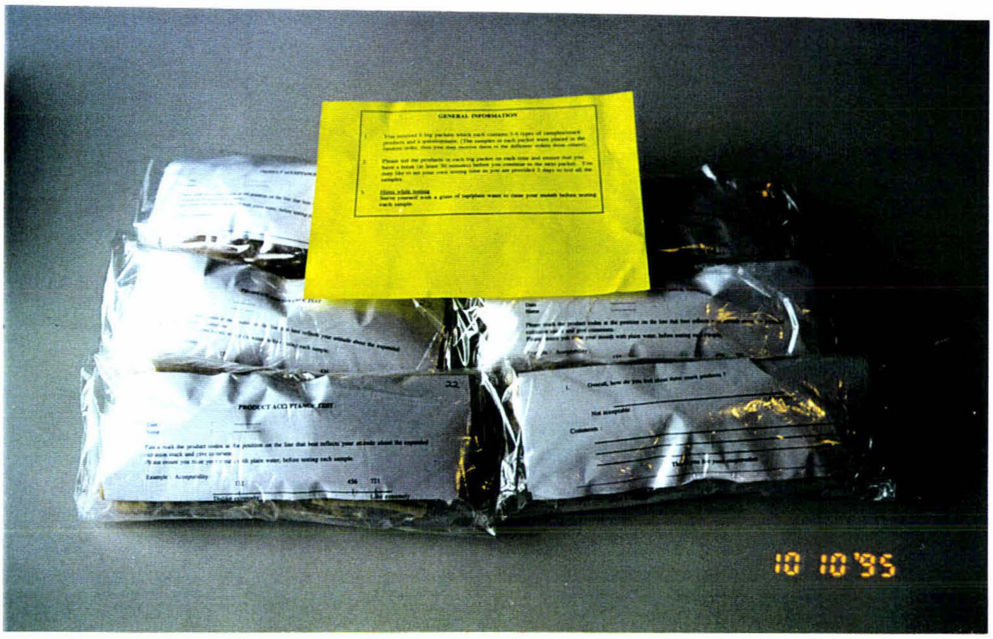


Figure 5.1 Samples delivered to the panellist

Each sample contained approximately 5 g of extrudate snack which was packed in a small sealed plastic bag. The samples were coded with a three digit number and the sequence of samples serving was randomized using Minitab version 10.5. The sample groups were selected by picking 5 to 6 samples using the randomized sequence code. The randomized samples code is shown in Appendix 5.5.

The panellist were asked to test one group of samples each time they did a test. They were provided 3 - 5 days to test all 31 samples. They were asked to set their own testing time and have at least 30 minutes rest, before they tested another group of samples. They were also asked to rinse their mouth with plain water every time before testing the sample.

The panellists indicated their degree of acceptability by giving a mark on a 10 cm line (Appendix 5.4). Each mark was then measured as a ratio of 10. The average of each sample acceptability (measured as this ratio) was entered into the Echip experimental design program to be analyzed. The longest interval, i.e. a mark on the most right side of the line indicated the most ideal product whereas a shorter interval showed a less acceptable product. The raw data of the panellist acceptability described in ratio is shown in Appendix 5.6.

5.4.2.4 *Specific mechanical energy*

The specific mechanical energy (SME) required in the extrusion process was calculated using Equation (3) (Section 4.5).

5.5 RESULTS: EFFECT OF INGREDIENTS AND PROCESS CONDITIONS ON THE EXTRUDATE CHARACTERISTICS

Thirty one samples were analyzed and the data was interpreted using Echip. The data from each trial were fitted with a quadratic model for the parameters MC, WAI, WSI, NSI, SME, breaking strength, colour and consumer acceptability. Raw data for the 31 extrudate are tabulated in Appendix 5.7, while the coefficients of the quadratic model are shown in Appendices 5.8 and 5.9.

5.5.1 Functional properties

5.5.1.1 *Moisture Content (MC)*

Table 5.6 shows the variables which affected significantly the extrudates' moisture content at the 99.9% level of significance ($P<0.001$), as well as the coefficients of the quadratic model. As indicated in Table 5.6 moisture of extrudates was significantly affected by the screw speed (cooking time), rice and tapioca content and water addition. Rice and water were positively correlated with extrudates' moisture, while tapioca and screw speed showed a negative correlation. Although percentage of soya added did not affect the extrudates' moisture, the combination of this variable with the others, namely screw speed, water addition or T4 had a significant influence on the extrudates' moisture content. The combination between rice and soya; and the interactive term of tapioca and soya also influenced significantly the extrudates moisture.

Table 5.6 Equation coefficient and variables which affected the extrudate's moisture content (MC)

MC	Coefficients	Variables
	7.170	1 (Constant)
	0.608	Rice
	- 0.968	Tapioca
	- 0.026	Screw speed
	14.257	Water
	- 4.467	Rice * Tapioca
	- 0.041	Rice * T4
	- 3.771	Soya * Tapioca
	- 0.049	Soya * Screw speed
	28.758	Soya * Water
	0.063	Soya * T4
	0.095	Tapioca * Screw speed
	-52.372	Tapioca * Water
	0.551	Screw speed * Water
	- 0.002	Screw speed * T4
	1.470	Water * T4
	-2.093	Rice * Rice
	2.828	Soya * Soya

The extrudate's moisture is affected by the presence of starch (rice and tapioca) in the raw materials. During extrusion, starches are subjected to relatively high pressure, heat and mechanical shear forces that can cause starch gelatinization, melting and fragmentation reactions (Lai & Kokini, 1991). Starch gelatinization is usually predominant in the environment with an excess of water above 63%. Wang *et al.* (1991) defines moisture above 63% as excess moisture. In an environment with limited water, melting of starch crystals is more predominant (Donovan, 1979). In expanded snack extrusion production, water in the environment is usually limited (12 - 16%). However, subjected to high temperatures, the polysacharide chains forming the starch granule, particularly those linked by hydrogen bonds (generally in the less ordered/ amorphous regions) would be disrupted allowing water to associate with the free hydroxyl group (Camire *et al.*, 1990).

The availability of rice and tapioca as the sources of starch would provide more free hydroxyl groups which facilitates swelling and water binding. Thus the increase of rice in the formulation increased the extrudates' moisture content. The combination between rice and tapioca also increased the moisture, further supporting that the starch granules were responsible for water binding. The increase in tapioca content, however, resulted in a decrease on product moisture. Explanation for this phenomenon could not be found in the literature. It is possible that moisture lost during storage could account for these differences. Water condensed on the package wall was observed in these samples.

The increase of screw speed significantly reduced the extrudates' moisture. This result was expected as an increase of screw speed would reduce extrusion residence time, thus, limiting the chance of water to associate with the starch hydrophillic groups. Increase of water addition (from 0.15 litre/hr to 0.2 litre/hr or equals to 16 - 20%w/w moisture) to the extruder during the process was also expected to increase the moisture content of the extrudates.

5.5.1.2 *Water Absorption Index (WAI)*

Result showed the extrudate's WAI was significantly affected by the addition of rice and soya ($P<0.05$). WAI values had a positive correlation with rice whereas soya gave a negative correlation. The equation model for WAI is shown below:

$$\text{WAI} = 4.463 + 0.750 \text{ Rice} - 1.009 \text{ Soya}$$

WAI values basically indicates degree of starch degradation, due to the extrusion process. The long polysacharide chains have been damaged and the hydrogen bonds exposed. These hydrogen bonds tend to absorb moisture from the environment. This explains the positive correlation with rice and clearly indicates that rice starch was modified during the process affecting WAI. This effect became more noticeable when the rice content in the formulation was increased.

Change in soya content should not affect the water absorption. However, the results indicated that the higher the level of soya in the formulation the lower the WAI values. This could be explained by the constraint between ingredient ratios set by the experimental design (section 5.3). The increase of soya decreases the rice and tapioca content, thus lowering the starch content in the formulation. It has been observed that starch in the formulation positively contributes to WAI.

Another possible reason is the interaction between the lysine contained in soya and reducing sugars, derived from the hydrolysis of starch enhanced by mechanical shear (Mercier & Feillet, 1975), from rice and tapioca starch in a Maillard reaction which could low the WAI value. This behaviour was also observed by Kim & Maga (1987) who extruded whey protein concentrate with cereal flour blends.

5.5.1.3 *Water solubility index (WSI)*

Table 5.7 shows the variables which affected the water solubility of the snack extrudates (P<0.1) along with the model coefficients determined by the computer program.

Table 5.7 Equation of coefficient and variables which affected the extrudate's water solubility index (WSI)

WSI	Coefficients	Variables
	21.492	1 (Constant)
	- 33.854	Rice * Soya
	879.281	Tapioca * Water
	0.025	Screw speed * T4
	53.554	Rice * Rice

Result showed that the process variables, screw speed and temperature affected the water solubility and increases in rice and soya reduced water solubility. The interaction of tapioca and water also increased WSI. The quadratic variable for rice (Rice * Rice) and the interaction between screw speed and T4 also gave positive correlation.

The water solubility index (WSI) is related to the degree of gelatinization of the starch. Gelatinized starch could solubilise in water more easily than ungelatinized starch (Lai & Kokini, 1991). Therefore gelatinized starch could give higher WSI values than ungelatinized starch.

The lack of significance level at P<0.1 for each individual variable (rice, soya, tapioca, screw speed, water addition and T4) shows that these variables did not have a significant effect on WSI under the range of conditions selected in this study. This could indicate the starch gelatinization has not completely occurred in the samples. Gelatinization needs an excess water environment. Under a limited water environment, the swelling forces are much less significant and complete gelatinization will not occur at the usual gelatinization temperature range. As the temperature increases and with the presence of limited moisture, the starch granules become progressively more mobile. At first, this mobile condition will enhance the replacement of inter-chain hydrogen bonds by water molecules, thus the polymers adsorb more moisture. This adsorption results in the growth and perfection of some crystalline regions which will make imbibition of water more difficult and will raise the gelatinization temperature range (Lai & Kokini, 1991).

The reduced water solubility observed when levels of rice and soya were increased can be explained by the possible reaction between rice and soya (Maillard reaction). The presence of soya can reduce the availability of starch for gelatinization decreasing WSI values.

Higher percentage of tapioca together with the amount of water added provided an environment for starch gelatinization, thus increasing the water soluble index (WSI). The increase on the rice level did not significantly affect WSI in the linear variable but significantly affected the quadratic variable. This would be indicating that the amount of starch in the formulation was not enough to provide significant variation among samples.

The increased screw speed and temperature were expected to affect significantly WSI values, as a higher shear rate combined with higher temperature promoted more starch macro degradation.

5.5.1.4 *Nitrogen solubility index (NSI)*

The effects of variables on nitrogen solubility index (NSI) are shown in Table 5.8 at the 95% level of significance ($P<0.05$).

Table 5.8 Coefficient of the model and variables which affected the extrudate's nitrogen solubility index (NSI)

NSI	Coefficients	Variables
	19.443	1 (constant)
	3.615	Rice
	-4.012	Soya
	0.007	Screw speed
	-14.187	Rice * Soya
	-103.756	Soya * Water
	193.562	Tapioca * Water
	0.540	Tapioca * T4
	13.971	Rice * Rice

The addition of rice gave a significant increase on the nitrogen solubility index (NSI), either as a linear or as a quadratic variable, while the addition of soya decreased the nitrogen solubility. The combination of soya and rice also decreased NSI. This trend was also obtained with the combination of soya and water. The addition of tapioca did not significantly affect NSI, however tapioca combined with water or T4 had a significant position effect on NSI. The increase of screw speed increased NSI.

At high temperatures and high shear rate, proteins denature and loose their original physical and chemical properties. The denatured protein is less soluble in water as the protein is unfold, the hydrophobic groups of the protein are exposed to the solvent and tend to interact with other hydrophobic groups from the same or other molecules. Therefore denatured protein gives lower values of nitrogen solubility (Singh, 1995).

During the extrusion process, high shear and high temperatures are used. This condition denatures the protein. Thus, as more soya is added, more protein is denatured, contributing to the decrease in nitrogen solubility. During protein denaturation process, water appears to be an essential ingredient. In an anhydrous state, proteins are fairly stable, 5 to 10 % water is sufficient to permit denaturation. This agrees with the result obtained which showed that higher water and soya content reduced the nitrogen solubility.

The combination of rice and soya also reduced the NSI. This result agrees to the result of Chauhan & Bains (1985, 1988) who extruded mixtures of rice and legume flours; and defatted soya and rice. However there was no explanation about this phenomenon could not be found.

Higher screw speed gives a lower residence times which provided less possibility for protein to denature. This explain the reason why NSI increased with increases in screw speed.

5.5.2 Specific mechanical energy (SME)

As shown in Table 5.9, the specific mechanical energy (SME) was affected by process conditions, eg. screw speed and T4. Interaction between ingredients and process conditions also affected SME.

Table 5.9 Variables and coefficient equation which affected the SME

SME	Coefficients	Variables
	200.331	1 (constant)
	0.316	Screw speed
	-1.229	T4
	0.918	Rice * T4
	84.555	Soya * Tapioca
	0.804	Soya * Screw speed
	-1.404	Soya * T4
	-1.607	Tapioca * Screw speed
	13.803	Screw speed * Water
	-100.039	Soya * Soya

Increased screw speed increased SME. This can be explained by the definition of SME given in section 4.5. As shown in this equation, SME depends on screw speed, torque and throughput. For a constant throughput increase on screw speed produces changes on SME which depended on the measured torque. In this study measured torque increased with screw speed.

T4 had a negative effect on SME. The decrease of melt extrudate viscosity with temperature resulting on lower measured torque could account for this result.

Soya had a positive effect on SME when combined with tapioca and a negative effect when the squared variable was considered. Sheard *et al.* (1984) found that when soya was extruded in the presence of carbohydrates, there is an interaction between soya and carbohydrates which contributes to the formation of a carbohydrate material embedded in a matrix of protein, resulting in high melt viscosity and therefore increased SME values.

On the other hand, high content of soya can form a soft viscoelastic dough during the melt transition (Moore, 1994), resulting in decreased SME values.

5.5.3 Physical properties

5.5.3.1 *Breaking strength*

This study showed that only the addition of rice had a significant effect on the breaking strength (P<0.2). A bigger force was required to break the sample as more rice was added. The relationship obtained is given by the following equation:

$$\mathrm{BS} = 3.189 + 1.039\ \mathrm{Rice}$$

Pan *et al.* (1992) observed that the amylose content in rice was correlated with crispiness and stickiness of the extrudate. The higher the amylose content, the less crispy and more sticky the product was. Rice flour used in this study was a non-waxy rice (white rice) which contains a high amylose content. It is possible that the bigger force needed to break the sample with increasing rice content (less crispiness) was due to its high amylose content.

5.4.3.2 *Colour measurement*

There was no significant colour difference (ΔE^*) in the snack produced under the different formulations and under different processing conditions. The products had a yellowish colour. However, a few variables significantly affected the colour parameters L^*, a^* and b^*. The effect of variables on L^*, a^* and b^* (P<0.5) are shown below:

$$L^* = 70.507 + 2.425\ \mathrm{Rice} - 2.981\ \mathrm{Soya}$$

$$a^* = 5.478 - 1.442\ \mathrm{Rice} + 1.661\ \mathrm{Soya} + 0.028\ \mathrm{Screw\ speed}$$

b^* = 27.889 + 1.345 Rice - 1.320 Soya - 0.038 Screw speed + 27.129 Water - 0.044 T4 + 45.999 (Soya * Water) - 114.272 (Tapioca * Water) - 0.003 (Screw speed * T4)

The addition of rice and soya affected colour values L^*, a^* and b^*. The addition of soya changed the colour towards red and yellow (brownish colour) and made the product colour became darker, while the addition of rice changed the colour towards yellow, green and lighter, thus the extrudate became light yellow colour.

The extrusion variables, screw speed, water and T4 significantly affected b^* values. Higher screw speed (less residence time) provided a less yellow colour. The addition of water enhanced the intensity of yellow while higher temperatures gave less yellow colour. The interaction between soya and water also increased the intensity of yellowness, however the interaction between tapioca and water; and between screw speed and T4 had converse effects on the intensity.

5.5 ACCEPTABILITY

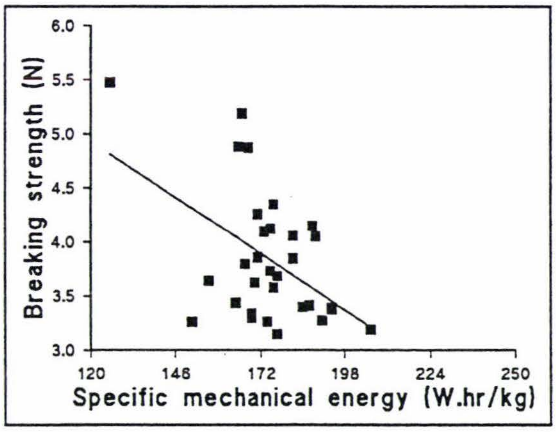
Acceptability of the snack was predominantly affected by the presence of rice, soya and the interaction between soya and T4. An increase of rice reduced the product acceptability. Conversely an increase in soya increased the product acceptability. The interaction between soya and T4, however reduced the product acceptability. The variables affecting consumer acceptability are shown below ($P<0.2$):

Acceptability = 5.429 - 0.925 Rice + 1.669 Soya - 0.068 (Soya * T4)

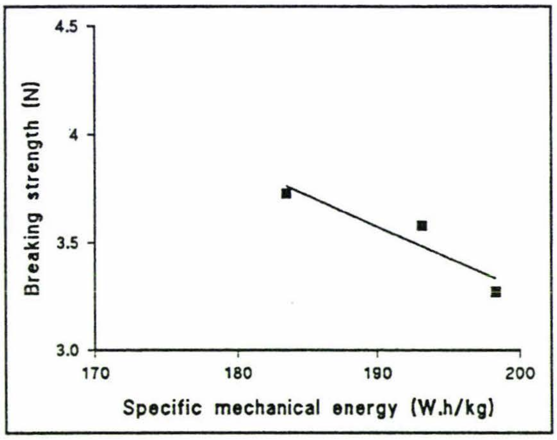
Crispiness was one of the most important attribute in the produced expanded snack. The addition of rice reduced the crispiness. The addition of soya improved the crispiness, which was a favourable characteristic to the consumers. However, when combined, temperature and soya had a negative effect on the product acceptability. Panellists found a burnt flavour. Acceptability probably decreased as a consequence of the high temperature denaturing effect on soya protein.

5.6 THE RELATIONSHIP BETWEEN SPECIFIC MECHANICAL ENERGY AND EXTRUDATE PHYSICOCHEMICAL PROPERTIES

Specific mechanical energy was negatively correlated with the breaking strength (Figure 5.2). The data for the 31 samples, obtained from different formulations and process condition in this study, suggested the general trend occurred in the relationship between the specific mechanical energy and breaking strength (Figure 5.2 (A)). A similar trend was obtained for the data plotted from individual formulation. Figure 5.2 (B) shows an example of the trend on formulation 7.



(A)



(B)

Figure 5.2 **Trend of the relationship between breaking strength and specific mechanical energy; (A) Data for the 31 samples, (B) Data for the formulation 7**

The figure shows that breaking strength decreases as the specific mechanical energy increases. During the extrusion process, the torque, screw speed and throughput determine the specific mechanical energy (SME). High screw speed and torque in the extrusion process produce high shear rate which causes more starch degradation and protein denaturation. This has an important effect on the extrudate viscosity. It has been recognized that molecular degradation of starch during the extrusion process decreases extrudate melt viscosity which results in more expanded products with weaker cell wall structure and lower breaking strength (Gomez & Aguilera, 1983).

Figure 5.3 shows the relationship between glass transition temperature (Tg) and SME. The general trend, although weak, appears to indicate a decrease in Tg value with SME. Glass transition temperature (Tg) is sensitive to molecular weight changes (Kaletunc & Breslauer, 1993). Low molecular weight polymers generally exhibit low Tg values. During extrusion process, high SME can cause degradation of starch to low molecular weight polymers which decreases extrudate Tg values.

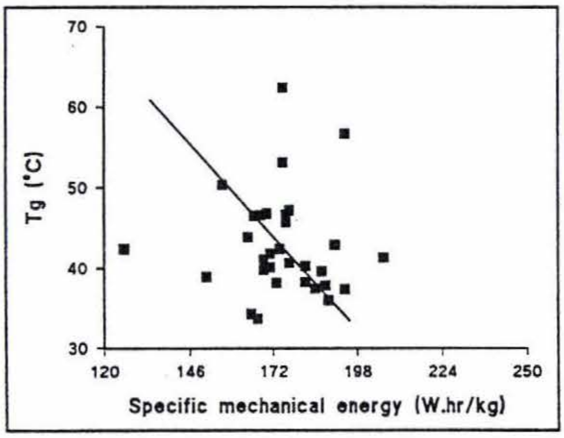
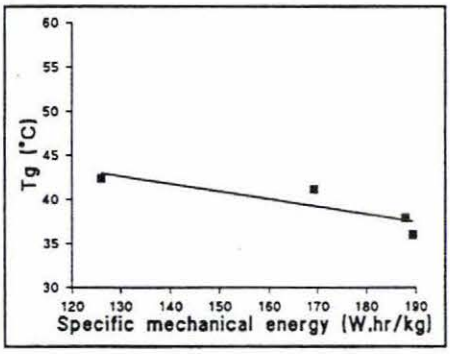
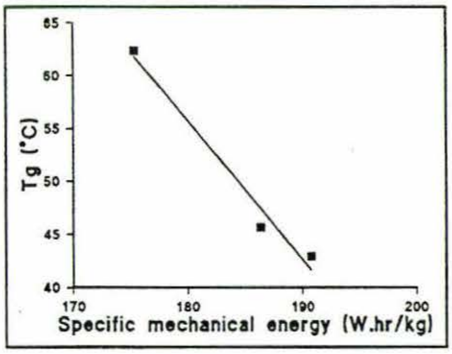


Figure 5.3 Trend of the relationship between Tg and SME on the scatter data of different formulation

Although the trend of the correlation was as expected, data is scattered. A possible explanation to the apparent lack of correlation is attributed to the fact that all the samples are included. These samples were prepared with different ingredients and different processing conditions. Figure 5.4 show a correlation when only one formulation is considered. As shown in the figure, a linear trend is obtained. Figure 5.4 is also indicating that molecular degradation, if measured by Tg values, follows different rates depending on the formulation.



(Formulation 5)



(Formulation 7)

Figure 5.4 Trend of the relationship between Tg and SME for selected formulations

The trend between WAI and SME is not well defined. It has been recognized that high SME disrupts starch macromolecules into smaller molecule size. Therefore, WAI increased as more disruption occurs. However Hoseney *et al.* (1992) observed that after a certain degree of molecular degradation, WAI starts to decrease. The peak point in the WAI vs SME curve was attributed to an excessive starch degradation losing its ability to bind water.

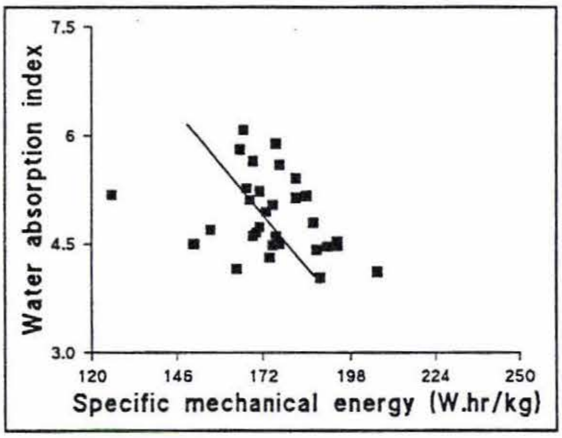


Figure 5.5 Trend of the relationship between WAI and SME

Figures 5.6 and 5.7 show trends between WSI and NSI with SME. Even though data is very scattered, results follow the expected trends. It is important to note that these trends represent the 31 trials which were carried out with different formulations and under different process conditions. Examples of the trend obtained from a single formulation are shown in Figure 5.8.

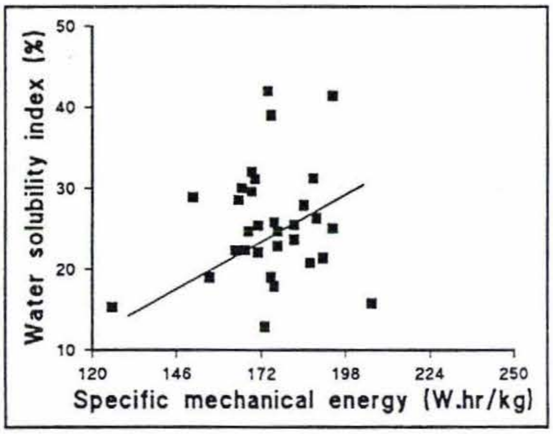


Figure 5.6 Trend of the relationship between WSI and SME

The trend noted in Figure 5.7, as expected, is showing that higher SME caused more protein denaturation, resulting in lower NSI values.

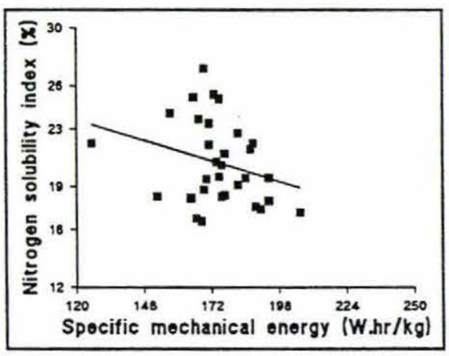
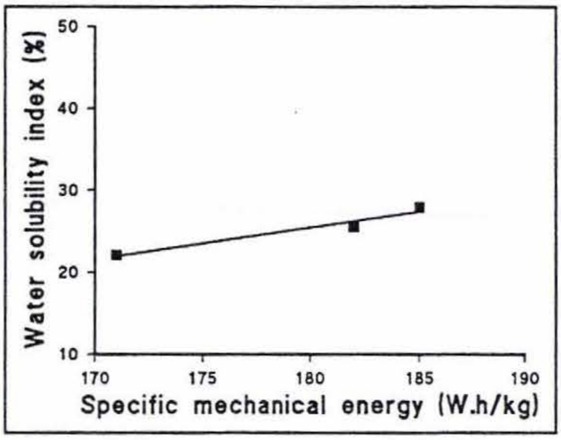
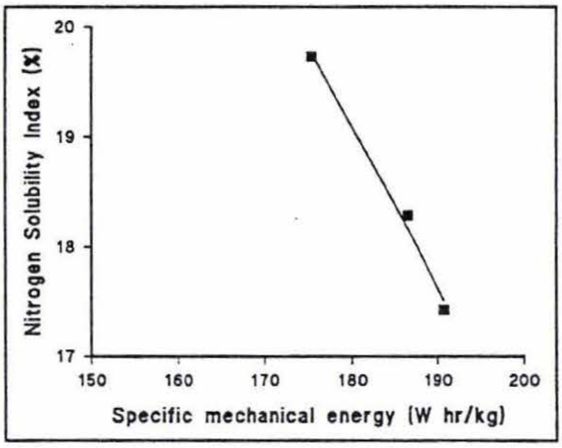


Figure 5.7 Trend of the relationship between NSI and SME



(A)



(B)

Figure 5.8 Examples of trend on a single formulation; (A) the relationship between WSI and SME, (B) the relationship between NSI and SME

A comparison study between properties of raw materials and extrudates (Appendices 5.3 and 5.6) showed that the extrusion process affected extrudate functional properties. The moisture and protein solubility decreased after processing, while water absorption index and water solubility index increased.

The moisture decreased from 13% to a range 5.8% - 10.2%. This decrease in moisture content is related to the flashing of the moisture during the product expansion at the extruder exit.

The protein solubility was significantly decreased after processing as the result of protein denaturation. The nitrogen solubility of samples decreased from the range of 42 - 56% (in the ingredients mixture) to 16.6 - 27.2% (in the extrudates).

Extrusion processing increased both WAI (from 1.95 - 2.05 to 4.11 - 6.08) and WSI (from 4.61 - 9.98% to 12.9 - 42%). This suggests that the functional properties of starch were changed during the extrusion process, probably due to starch degradation.

5.7 CORRELATION BETWEEN CONSUMER ACCEPTABILITY AND EXTRUDATE PHYSICAL CHARACTERISTICS

It has been recognized that consumer acceptability of sensory attributes are affected by the physical characteristics of the food product, such as texture and colour. Therefore if a relationship between these measurements could be obtained, product attributes could be carried out through instrumental analysis which are normally less time consuming and provides more reproducible results. Understanding the relationship of consumer acceptability and instrumental analysis assists in maintaining the product quality. Moreover an identification of the favourable physical characteristics in a food product could predict the product acceptance.

The relationship between consumer acceptability and extrudate breaking strength (measured as a texture parameter) of all the samples obtained in the extrusion trials is shown in Figure 5.9. Despite of the scattered data as a result of the different formulations and process conditions used, the trend shows that a decrease in breaking strength improves consumer acceptability. Lower values of breaking strength appears to indicate crispier snack, an attribute preferred by the consumers.

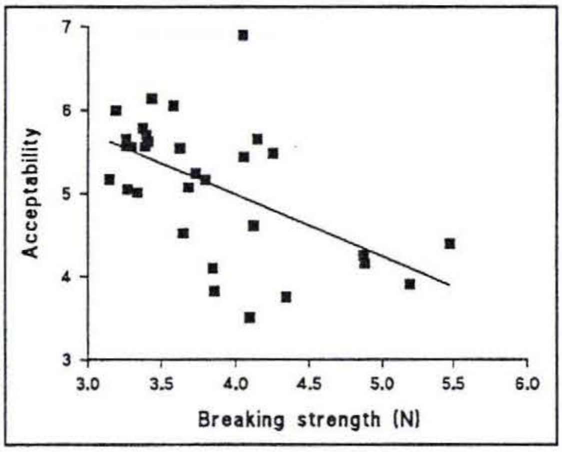
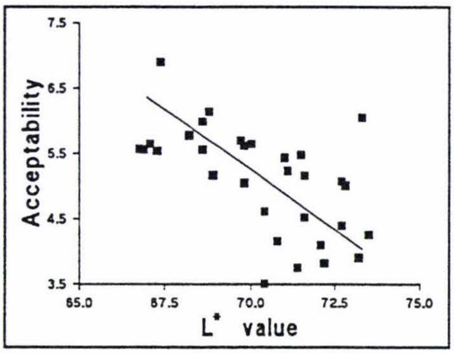
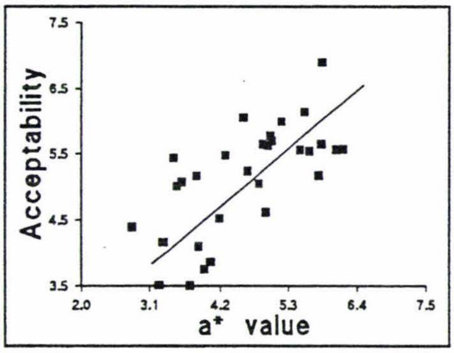


Figure 5.9 Relationship between consumer acceptability and extrudate breaking strength; the data of all 31 samples

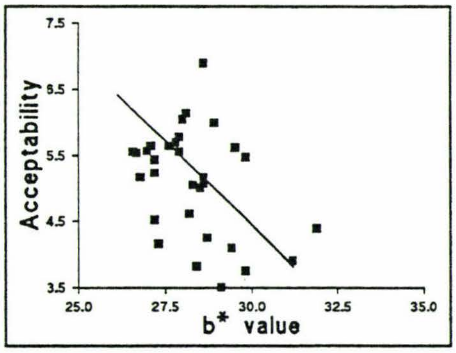
Figures 5.10 (A),(B),(C) show the correlation between consumer acceptability and colour measurement (L^*, a^*, b^* values). These graphs clearly illustrate the preference of the consumer for extrudates with a brownish yellow colour. The acceptability decreased as L^* and b^* values increased, whereas increased with higher a^* values.



(A)



(B)



(C)

Figure 5.10 Correlation between consumer acceptability and colour measurements of (A) L^*; (B) a^*; (C) b^*, respectively

Overall there was a correlation between consumer acceptability, breaking strength and colour. The snack base appears to be more acceptable when has less breaking strength and brownish yellow colour.

5.8 CONCLUSION

The properties of materials in the formulation changed during the extrusion process. The moisture and protein solubility decreased after the processing while the WAI and WSI increased, indicating profound changes in the chemical compounds forming the ingredients (starch degradation, protein denaturation and interaction between starch and protein).

Among the ingredients (rice, soya and tapioca), rice and soya appears to affect more to the final product than tapioca. Tapioca affected the extrudate moisture content. It had less effect on WAI, WSI and NSI value, although its combination with water affected the WSI.

Increase in rice increased MC, WAI, NSI and BS, while increase in soya reduced the protein solubility. The interaction between rice and soya reduced starch degradation and protein denaturation, as noted by the decrease in WSI and NSI values. In addition the reaction also affected the extrudate colour.

Water addition clearly affected the extrudate moisture and contributed to the changes that the chemical components have undergone extrusion variables, screw speed and temperature influenced the snack characteristics.

The extrusion operating conditions also affected the characteristics of the final product. Increase in screw speed reduced the extrudate's moisture content, protein solubility and colour as the result of product shorter residence time in the extruder. Increase in temperature at the fourth barrel accelerated chemical changes during the extrusion process. The combination of T4 and soya decreased the consumer acceptability.

The snack base with lower breaking strength and brownish yellow colour was preferred. A decrease in breaking strength improved consumer acceptability as lower values of breaking strength appears to indicate crispier snack. The breaking strength could be reduced by increasing the specific mechanical energy (SME) which can be measured with torque, screw speed and throughput. However, higher SME apparently results in starch degradation and protein denaturation.

EXTRUDED SNACK FORMULATION

In the preliminary market and consumer study (described in Chapter 3), the more important product attributes of an extruded snack were defined as texture and flavour. A preferred texture was obtained during the extruded snack base formulation, while a preferred flavour was developed through a consumer test of the optimum snack base coated with various flavour powders. Figure 6.1 shows a flow diagram for the extruded snack formulation.

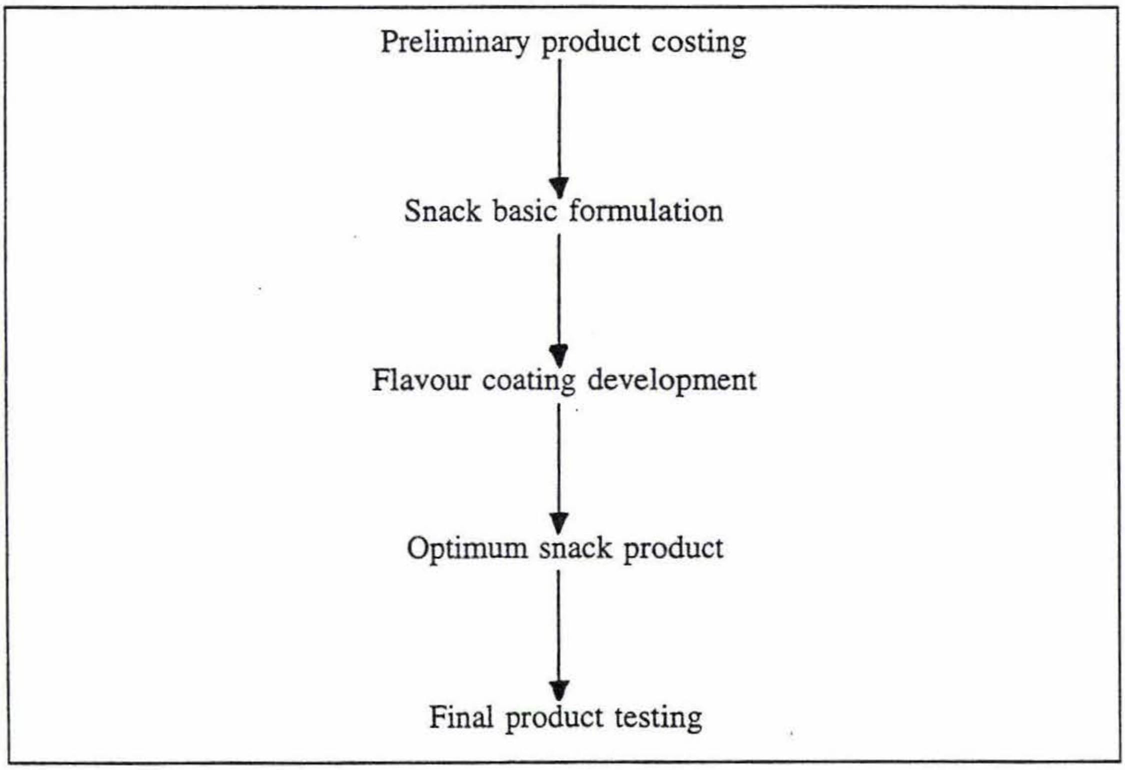


Figure 6.1 Stages on the extruded snack formulation

6.1 SNACK BASE FORMULATION

6.1.1 Introduction

The different formulations and processing conditions set by the experimental design were used to produce 31 samples. These samples were tested in both their sensory, physical and functional properties. Results of these measurements were described in Chapter 5.

The aim of this chapter is to describe the steps followed to find the most acceptable snack base to be used in further snack development stages. To meet this aim a snack base was formulated along with the study on extruded snack properties (Chapter 5). This chapter describes methods to screen formulations and process conditions used to develop a snack which is acceptable to consumers.

6.1.2 Method in obtaining the snack base formulation

The snack samples were produced as described in section 5.3. These samples were tested using a line scale acceptability test, as described in section 5.4.2.3. The data obtained were analyzed statistically using an ANOVA two-way test, and carried on with a Tukey's Honestly Significant Difference test.

6.1.3 The optimum snack base formulation

ANOVA indicated that there was significant differences in acceptability among the products ($P<0.05$). The details of the statistical analysis are shown in Appendix 6.1. As shown in Figure 6.2, trial 22 was the most acceptable snack base with a mean and a standard deviation of 6.9 and 1.9, respectively. The basic formulation and conditions for trial 22 are given in Table 6.1.

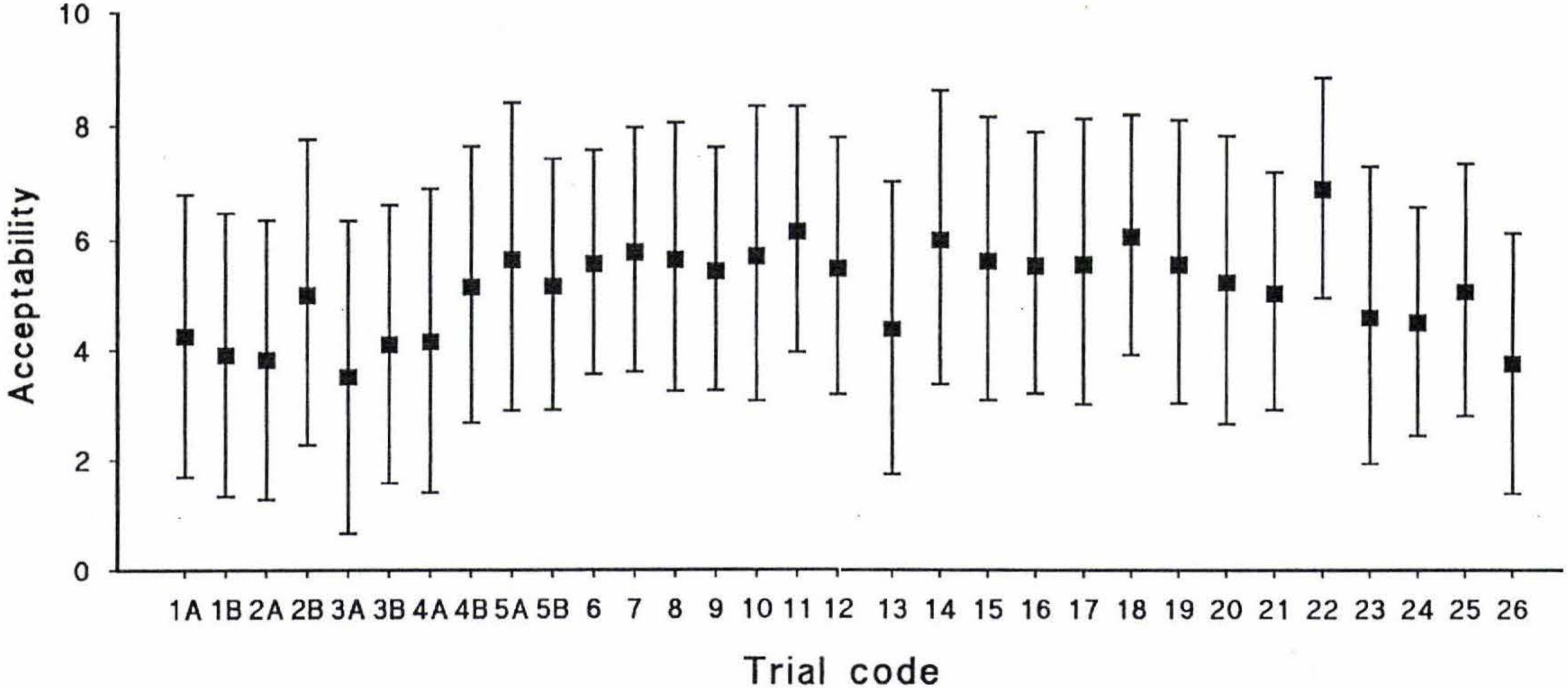


Figure 6.2 Acceptability of the snack base (trial codes refer to formulations described in Appendix 5.1)

Table 6.1 The most acceptable snack base formulation and process

Variable	Value
Ingredients:	
Corn meal	59.6 %
Defatted soya flour	28 %
Rice flour	12 %
Tapioca flour	0 %
Baking soda	0.4 %
Process condition:	
Screw speed	300 rpm
Water addition	0.15 kg/hr
Feed rate	0.55 rpm ≈ (4.31 - 4.55 kg/hr)
Temperature at 1th zone (T1)	40°C
Temperature at 2th zone (T2)	80°C
Temperature at 3th zone (T3)	115°C
Temperature at 4th zone (T4)	140°C

The snack base cost was below the constraint imposed to the product cost (Rp.2000/kg), therefore the product of trial 22 was selected as the snack base formulation for further development. The cost of each sample is shown in Appendix 6.2.

The development of the snack base was tested without flavour as the aim was to obtain an acceptable snack texture for the consumers. To produce the final snack product, the snack base had to be coated with flavour, since flavour was one of the important attributes in consuming a snack. The flavour development of the snack product was described in the following section.

6.2 FLAVOUR COATING FORMULATION

The most acceptable snack base (Trial 22) obtained in the extruded snack base development described in section 6.1 was used for the flavour development stage. Flavours used were provided by six commercial flavour companies. They were screened using several sensory testing stages to obtain the most acceptable flavour to be tested further on a large consumer test. Panellists for sensory evaluation were Indonesian who live in Palmerston North. They were expected to be the closest model for the potential target market.

6.2.1 Aim

Even though the optimum snack base had a high acceptability score, the panellists generally commented that all products had a relatively bland taste. Therefore the general aim of the flavour development was to improve the product acceptance by coating the extruded snack with a suitable flavour.

Specific objectives were:

- to improve the snack product acceptability;
- to obtain the optimum proportion of flavour to be used. This is a compromise between palatability and cost.

6.2.2 Flavour development procedures

Flavours were supplied by six commercial flavour companies, Quest International, NZ Ltd.; Bush Boake Allen, NZ Ltd.; Griffith Laboratories, NZ Ltd.; Haarmann & Reimer, NZ Ltd. and New Zealand Dairy Board, NZ. The companies were advised to provide flavour samples for an extruded snack, targeted for the Indonesian market.

The companies were also informed that the most preferred flavours for Indonesian market are: chicken, cheese, barbecue, hot and spicy and corn flavour. Corn is a new flavour which is gaining a large share in the Indonesian market as indicated by the space used in supermarket shelves (section 3.1.2).

20 different flavours were received. The types of flavour, cost and dosage recommendation given by the suppliers are shown in Table 6.2.

6.2.2.1 *Sample preparation*

As a starting point the dosage recommended by the supplier was used to flavour the snack base. Thirty grams of oil were mixed with 6 - 15 g of flavouring powder, depending on the dosage used, to form a slurry. Sixty grams of snack base were heated at 70°C for 10-20 minutes. This base was then coated with the slurry by mixing it in a drum mixer (Ringcone model NRXMK-400). The drum was run for 10 - 20 minutes at a low speed. The coated snack was packed in polypropylene bags and sealed for the sensory test described in section 6.2.2.2.

Several additional ingredients such as salt, sugar, whey protein powder and colour were also added to the slurry, as suggested by flavour suppliers. A list of added ingredients is given in Table 6.3. The ingredients were added to improve the palatability and acceptability. The whey protein concentrate powder was used as a carrying agent, as it could reduce the saltiness or colour intensity of the flavour powder. A combination mixture among cheese powder was also carried out to reduce the colour intensity.

A sensory test was carried and the result of the sensory testing was used to identify a product for further development.

Table 6.2 Flavour samples used in the flavour development

No.	Flavours	Cost (Rp./kg)[a]	Usage dosage[b] (%)	Company
1.	Cheese powder - ATCP 1013	7800.00	15	NZ Dairy Board
2.	Cheese powder - ATCP 1014	11242.00	15	NZ Dairy Board
3.	Cheese powder - ASP 2001	6457.00	15	NZ Dairy Board
4.	Cheese powder - A 2003 SS	6413.00	15	NZ Dairy Board
5.	Cheese & onion - AFP 355	9240.00	15	NZ Dairy Board
6.	Sour cream & chives - 9110	12554.50	6	Griffith Laboratories
7.	Chicken flavour base - 7718	21415.50	6	Haarmann & Reimer
8.	Crispy fried chicken - APO 2656	14750.50	10	Quest International
9.	Chicken saroline - E 4.6264	8492.75	6	Bush Boake Allen
10.	Mexican chicken 2 - E 5.6064	13588.40	6	Bush Boake Allen
11.	Barbecue seasoning - 9127	11077.50	2-3	Griffith Laboratories
12.	Hot 'n spicy barbecue - E 5.6065	12332.95	6	Bush Boake Allen
13.	Barbecue saroline - E 5.6000	9157.40	6	Bush Boake Allen
14.	Barbecue chip saroline - E 4.6150	9157.40	6	Bush Boake Allen
15.	Cajun - 5492	10339.00	6	Griffith Laboratories
16.	Curry - 7314	12554.50	6	Haarmann & Reimer
17.	Ethnican - QZ 02346	12554.50	10	Quest International
18.	Nacho - 9166	14750.50	6	Griffith Laboratories
19.	Spicy jalapeno seasoning - 9161	12554.50	7	Griffith Laboratories
20.	Roasted Corn - QZ 02352	25847.50	10	Quest International

[a] NZ$ 1 = Rp.1477 (dated 5 July 1995)
[b] Recommended by the suppliers

Table 6.3 The adjustment of flavouring agent for the snack formulation and the total product cost

	Flavours	Flavour powder[a] (g)	Other ingredients (g)	Total snack cost (Rp./kg)	Further screening (+/-)[b]
1.	Cheese powder - ATCP 1013	15	WPC = 5 Salt = 1 Tart = 0.02	3201.36	--
2.	Cheese powder - ATCP 1014	15	-	3276.31	--
3.	Cheese powder - ASP 2001	20	-	2768.39	--
4.	Cheese powder - A 2003 SS	20	-	2760.39	+
5.	Cheese powder - AFP 355	15	-	2990.31	--
6.	Cheese powder - AFP 355 Cheese powder - ASP 2001	5 10	Tart. = 0.2 g	2852.06	+
7.	Cheese powder - ATCP 1014 Cheese powder - ATCP 1013	10 5	WPC = 5 g Salt = 1 g Tart. = 0.02 g	3511.40	--
8.	Sour cream & chives - 9110	10	WPC = 10 g Tart = 0.1 g	3895.27	+
9.	Chicken flavour base - 7718	5	WPC = 4 g	3342.02	+
10.	Crispy fried chicken - APO 2656	13	Tart. = 0.14 g	3653.84	+
11.	Chicken saroline - E 4.6264	6	WPC = 2 g Sugar= 0.55 g	2550.62	+
12.	Mexican chicken 2 - E 5.6064	6	-	2676.18	+
13.	Barbecue seasoning - 9127	7	-	2607.47	+
14.	Hot 'n spicy barbecue - E 5.6065	7	-	2698.07	+
15.	Barbecue saroline - E 5.6000	6	-	2399.24	+
16.	Barbecue chip saroline - E 4.6150	6	-	2399.24	--
17.	Cajun - 5492	17	-	3281.73	+
18.	Curry - 7314	15	-	3463.81	+
19.	Ethnican - QZ 02346	13	Salt = 1 g Sugar = 2 g	3233.35	+
20.	Nacho - 9166	15	-	3777.52	+
21.	Spicy jalapeno seasoning - 9161	10	-	3009.27	+
22.	Roasted Corn - QZ 02352	7	Sugar = 7 g SY= 0.03 g Tart.= 0.06 g	3584.89	+

[a] For 60 g snack base
[b] (+/-) ; + = carried on for further screening; -- = screened out
WPC = Whey protein concentrate powder; Tart. = tartrazine (colouring agent); SY = sunset yellow (colouring agent)

6.2.2.2 *Flavour screening method*

The flavours were screened through 5 different stages to identify the most acceptable snack product. The procedure for the flavour development screening is schematically shown in Figure 6.3.

In the first screening stage, the flavour samples received from the suppliers were applied to the snack base and evaluated by a small group of 3 persons. The first screening was basically to obtain an acceptable level of flavour dosage to use in the formulation. The cost of the optimized snack ingredients was calculated using linear programming and check with the cost requirement (not over than Rp.4000/kg) (Hawkes, 1995, Personal Communication).

For the cheese flavour, various combinations of supplied cheese powders were done to dilute the flavours as suggested by the supplier. Two cheese flavour combinations were added to the 20 flavours supplied from the suppliers, thus 22 flavour were used in the sensory test. The flavours which failed to meet either the panellist's acceptable level or the cost limit were eliminated and after the first screening only sixteen flavours remained.

For the second screening stage, the flavours remaining were categorized into groups, flavours of a similar type were grouped together. Six groups of flavours were obtained, cheese, chicken, barbecue, spicy, savory/mexican and corn. Each group was then tested to obtain the most preferred flavour in each group by ranking them. A small group of 8 panellists were used for this screening stage.

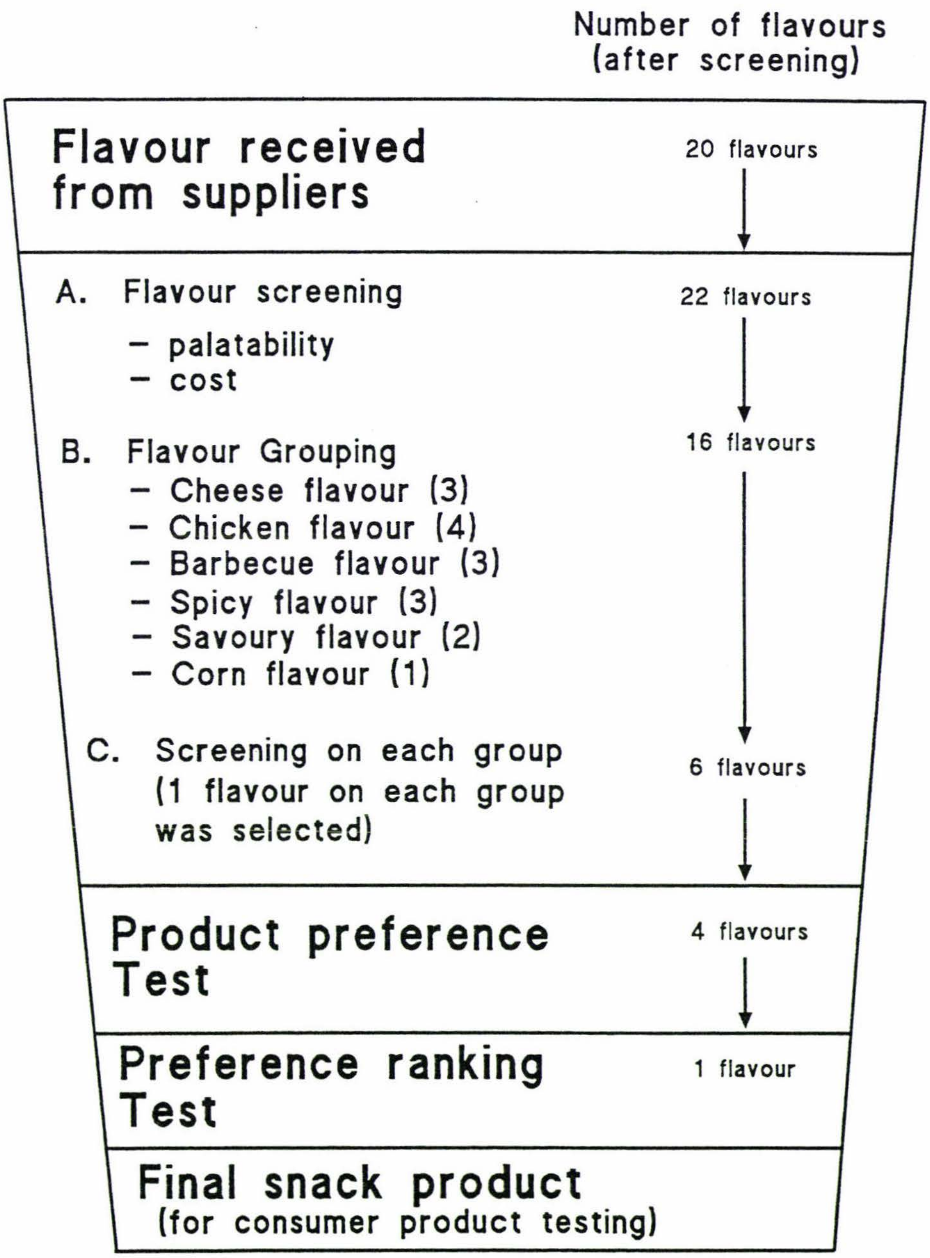


Figure 6.3 Flavour screening stages

The panellists were asked to evaluate the products in each group and completed a questionnaire. They were also asked to give comments about how to improve the product acceptance, particularly the degree of saltiness, sweetness and flavour intensity. Appendix 6.3 shows the questionnaire used in this second screening stage. The data were analyzed using a weighted index rank sum to obtain a weighted index rank sum mean (WIRSM) for each sample. The sample which had the highest total mean was utilized for further evaluation. When two WIRSM of samples in a same group were similar, the products were ranked again to find the most preferred one. As there was only 1 sample available in the corn group, the sample was carried forward for further evaluation. It was difficulty to obtain other corn flavours from different suppliers, as it is a flavour not commonly available for the New Zealand snack market.

As indicated in Figure 6.3, six flavours were selected from the second screening stage for further evaluation. These samples were then tested using a product preference test with a seven point hedonic scale. The attributes evaluated were colour, aroma, flavour, overall appearance and overall preference. The test procedure is described in section 4.4.4. Thirty people participated in the testing and completed in the questionnaire shown in Appendix 6.4.

The product preference test showed that four samples had a similar preference. Therefore these samples were screened down using a ranking test, described in section 4.4.5 to select the product that would be considered for the final product testing. The format of questionnaire for the ranking test is shown in Appendix 6.5.

6.3 FLAVOUR DEVELOPMENT RESULTS

6.3.1 First flavour screening

Twenty two different flavoured snacks were obtained from 20 types of flavours received from commercial flavouring companies. Two of them were a mixture of various cheese powders. Cheese powder AFP 355 had a high cheese concentration, thus it was suggested by the company to be mixed with other weaker cheese flavour or ingredients as carriers.

Table 6.3 shows the 22 types of flavours applied to the snack base and their product cost. The cost calculation is shown in Appendix 6.6. From the 22 flavoured snacks, 16 products remained for the next screening.

Six products, five cheese flavoured and 1 barbecue flavoured were rejected, because they were not palatable to the panellists. The flavours of cheese powder ATCP 1013, ATCP 1014, ASP 200 and the mixture of ATCP 1013 and ATCP 1014 had less cheese flavour and were considered to have a milky flavour, while cheese powder AFP 355 had a very strong red colour. The barbecue chip Saroline - E 4.6150 was also rejected as it had a strong typical spicy and herbal flavour, such as ***capulaga*** which is considered inappropriate to use in barbecue. The flavours with less cheesy flavour could be improved by adding more flavour powder. However, this would increase the product cost.

6.3.2 Second flavour screening

For the second stage of the screening, the sixteen remaining flavoured snacks were grouped into 6 categories, i.e. cheese, chicken, barbecue, spicy, savory/mexican and corn.

The flavour of sour cream & chives was categorized into the cheese group, as it had a dairy flavour. This flavour was new for Indonesian consumers as there was no such flavour in the market when this research was run. The flavours such as curry, ethican and cajun were included into the spicy group, while the savory flavour consisted of nacho and jalapeno flavours. The flavours on each group were ranked. The samples with the highest weighted index rank sum was nominated for further testing. The nominated flavours of each group are shown in Table 6.4 ranked by the weighted index rank sum while the detail of the weighted index rank analysis is shown in Appendix 6.7.

Table 6.4 Flavour grouping and order of preference

Flavour group	Type of flavours	Weighted index rank sum Σ (x.n)[1)]	Flavour selected from each group
Cheese	1. Cheese powder - AFP 355 & ASP 2001 2. Sour cream & chives - 9110 3. Cheese powder - A 2003 SS	21 11 6	Cheese powder - AFP 355 & ASP 2001
Chicken[a)]	1. Chicken saroline - E 4.6264 2. Mexican chicken 2 - E 5.6064 3. Chicken flavour base - 7718 4. Crispy fried chicken - APO 2656	23 22 18 17	Mexican chicken 2 - E 5.6064
Barbecue[b)]	1. Barbecue saroline - E 5.6000 2. Barbecue seasoning - 9127 3. Hot 'n spicy barbecue - E 5.6065	18 17 13	Barbecue saroline - E 5.6000
Spicy	1. Cajun - 5492 2. Curry - 7314 3. Ethnican - QZ 02346	21 16 11	Ethnican - QZ 02346
Savoury/ mexican	1. Nacho - 9166 2. Spicy jalapeno seasoning - 9161	14 10	Spicy jalapeno seasoning - 9161
Corn	1. Roasted Corn - QZ 02352	-	Roasted Corn - QZ 02352

[1)] x = number of participants on each rank; n = factor for the degree of preference, higher n value for the higher preference (n = 1 for the least preference)

[a)] & [b)] were tested again to obtain the most preferred.

The panellists generally accepted the taste and the flavours intensity of the samples. For the chicken and barbecue flavour groups, there were two flavours which had a similar total score (Appendix 6.7). The total score for the chicken saroline E 6264 and Mexican chicken 2-E 5.6064 were 23 and 22, respectively. The chicken saroline E 6264 had a slightly lower total score, but three of eight panellists chose it on their first preference and one panellist chose it on his second preference. For the Mexican chicken 2-E 5.6064 only two of eight panellists considered this flavour as their first preference whereas four panellists put it as the second preference. This obviously inclined the selection towards the Mexican chicken 2-E 5.6064 flavour.

Something similar occurred with the barbecue seasoning - 9127 and barbecue saroline E 5.6000 flavours which had the total scores of 17 and 18, respectively (Appendix 6.7). The hot 'n spicy barbecue E 5.6065 had a slightly lower total score and four of eight panellists selected it as the first preference and one panellist did as the second preference. Two panellists preferred the barbecue saroline E 5.6000 as the first choice and six panellists chose it as the second one. The later flavour was selected as the more acceptable flavour.

The small difference obtained in the total scores can be attributed either to the use of weighted index rank analysis or the limitation of using a small number of panellists during the testing. The small difference in the total score is a very important issue to consider because it may cause a misinterpretation of the data during the product development. A product may have a slightly higher potential market than others, however, because of the wrong decision taken from an inappropriate testing, the product developer may lose the market.

The weighted index rank analysis gives numerical weights to indicate the degree of importance on each rank (Green *et al.*, 1988). These numerical weights will affect the total score. For example the first rank normally has a higher numerical weight than the second one, however, the second choice could have a higher weighted index rank sum if more panellists rank the product in the second option.

The small number of panellists may not statistically represent the population and provide misleading data. Therefore, to avoid a misinterpretation of results, another ranking test was set using the same samples of both chicken and barbecue groups. The number of panellists was increased to 14 people. This number of panellists is still small to represent the population, however, the increase of six members could provide a better definition of the consumer preference. In addition a large sensory panel during the early product development stage is not recommended in order to control confidentiality issues and awareness of other companies before the launching of the product.

The result of this second sensory test is shown in Appendix 6.8. Mexican chicken 2 - E 5.6064 and barbecue saroline E 5.6000 were selected for further flavour screening (Table 6.4).

6.3.3 Third flavour screening

Six flavours, one flavour from each group were used in the third screening test (Figure 6.4). Twenty eight panellists expressed their degree of preference towards colour, samples appearance, aroma, flavour and overall product using a 7 points hedonic scale. A summary of the samples preference for each group is shown in Table 6.5 and the details of panellists' responds for each sample are shown in Appendix 6.9. Appendix 6.10 illustrates results of the ANOVA and Tukey's honestly significant different test analysis.

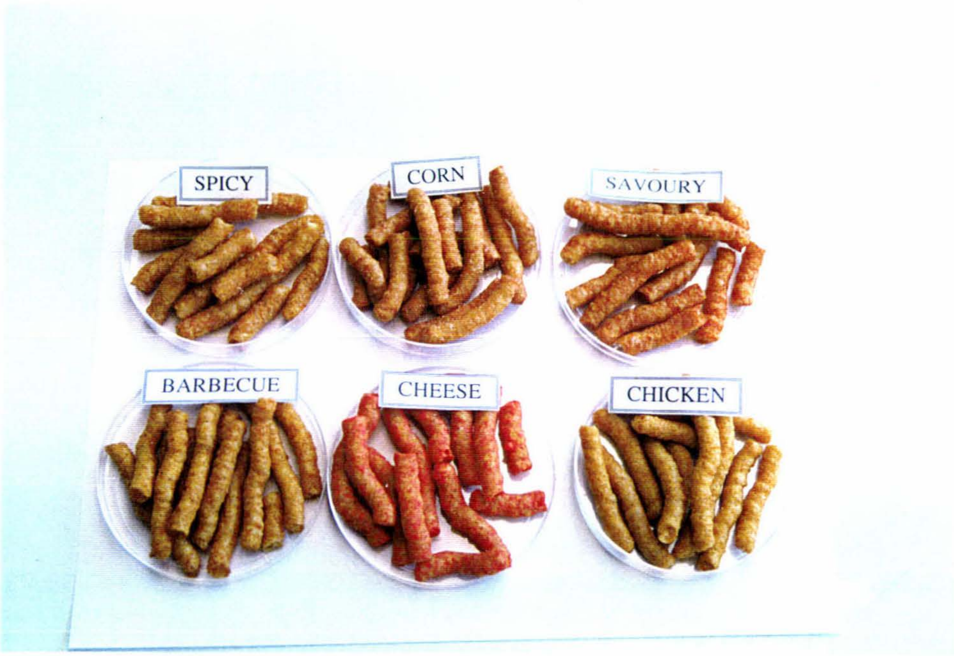


Figure 6.4 Six different flavoured snack samples

Table 6.5 The product preference on each flavour group[1)]

Parameters	Preference on each flavour (average values are used)					
	Cheese	Chicken	Corn	Savoury	Barbecue	Spicy
Overall preference	3.82[a] [2)]	3.71[ab]	3.0[abc]	2.86[abc]	2.79[bc]	2.5[c]
Overall appearance	4.64[a]	3.43[b]	3.43[b]	2.68[b]	2.79[b]	2.82[b]
Flavour	3.07[ab]	3.57[a]	3.29[a]	2.68[ab]	3.0[ab]	2.14[b]
Aroma	3.75[a]	3.29[ab]	2.89[ab]	2.54[b]	3.04[ab]	2.89[ab]
Colour	4.75[a]	3.82[ab]	3.18[bc]	2.32[c]	2.61[c]	2.71[c]

1) A lower mean indicates a higher preference score (1 = like very much; 7 = dislike very much)
2) Different letter at the same line indicates significantly difference on treatments ($P<0.05$)

Among the six samples, the spicy sample had the highest overall preference mean, (2.5). The panellists enjoyed the spicy flavour on the product which provided a mixture of salt, sweet, sour, spicy and a bit hot.

The barbecue, spicy, savory and corn were not significantly different in overall preference. The savory sample was preferred due to its appearance and aroma. The overall likeness was decreased because of its flavour. A panellist commented the flavour was too hot, while 5 people believed the hotness did not appear to come from chili flavour. The hotness was too pungent and strong for them. Indonesian consumers prefer chili as the source of hotness taste to capsicum or pepper.

Barbecue and corn flavours are in vogue in the Indonesian snack market, in addition to chicken and cheese. Many commercial snacks are available in these flavours. However, barbecue and corn samples had slightly lower mean than either savory and spicy samples. Although there was no significantly difference in statistical analysis, these two samples were less preferred than the spicy ones. In order to get a complete conclusion about the results, a ranking preference test was conducted with the corn, spicy, barbecue and savory samples. Table 6.6 shows the number of people that chose the sample on each rank. The spicy flavour had the highest weighted index rank sum (80) and Z-value.

Table 6.6 Ranking preference test among corn, savory, barbecue and spicy flavours

Products	Number of panellists on each rank (persons)[a]				Weighted index rank sum $\Sigma(x.n)$[b]	Total Z values[c]
	I	II	III	IV		
Spicy	12	5	6	5	80	0.99(1)
Corn	11	7	5	5	79	0.93(2)
Savoury	4	10	6	8	66	-0.38(3)
Barbecue	1	6	11	10	54	-1.54(4)

[a] Rank I = the most preferred sample; rank IV = the least preferred sample
[b] x = number of participants on each rank
n = factor for the preference rank (n = 4 for rank I; n = 1 for rank IV)
[c] Related to importance proportion (Thurston case V)
Number in the bracket indicates the preference for each flavour

6.4 CONCLUSION

The most preferred product was made from 28% defatted soya flour, 12% rice flour, 59.6% corn grits and 0.4% baking soda. These mixture ingredients were processed in a twin screw extruder (Clextral BC-21) with a feed rate of 4.47 kg/hr. The four barrel temperature zones were set up on 40°C, 80°C, 115°C and 140°C, respectively and 150 ml/hr water was pumped to the barrel. The screw was run at a speed of 300 rpm.

The snack acceptance was improved by coating the samples with flavours and the most preferred flavour was the spicy one (Ethican - QZ 02346; Quest International). A product with the above characteristics was selected for further testing in a large scale consumer test.

FINAL CONSUMER PRODUCT TESTING

Chapters 5 and 6 give an account of how the product was designed, manufactured and tested in both its physical and sensory characteristics. Results of the testing clearly showed that the product was acceptable to Indonesian consumers living in Palmerston North. Even though the results obtained and described in Chapter 6 were very encouraging and enabled the definition of an acceptable product, this design cannot be directly translated to the Indonesian target market without final consumer testing in Indonesia. The small number of panellists in Palmerston North was another concern to draw definitive conclusions of Chapter 6. Chapter 7 describes the final consumer testing of the product which was conducted in Indonesia among University students and office workers.

7.1. AIM OF FINAL CONSUMER PRODUCT TESTING

The aim of the study was to measure product acceptability of the new extruded snack in Indonesia.

Specific objectives were to :

- evaluate the product concept by the target consumers in Indonesia
- establish the performance of the product as itself and in comparison with similar product in the market
- determine consumer purchase intention of the developed product

7.2. PROCEDURE IN TESTING THE SNACK

7.2.1 Selection of consumers and testing venue

Consumer panellists for the final testing were selected from Indonesian who were considered as the target consumers for the developed snack, i.e. adults over 18 years of age. The total number of panellists was 147.

University students and staff from various departments at the University of Wydia Kartika and University of 17 Agustus in Surabaya, Indonesia were selected because of the convenience in setting the sensory test. The testing schedule was delivered informally (word of mouth) to the panellists before the event. The panellists were informed about the testing purpose, date and were invited to participate in the testing.

The test was set using several groups consisting of 15 - 20 people from the same department. The venues were either in a classroom or in a laboratory central location. The tests were normally held in the classroom after the panellists finished their lectures. The tests at the University of Widya Kartika were held on the 19 - 20 December 1995, while at the University of 17 Agustus the tests were held on the 21 - 22 December 1995.

7.2.2 Sample preparation

Approximately 20 g of four types of extrudate snack samples; *Cheetos*, *Chiki*, *Bigun* and the *new product sample* were packed in self adhesive plastic bags. The samples were coded and no brand name or information about the extrudate were printed on the plastic bags. The example of samples evaluated is shown in Figure 7.1.

7.2.3 Questionnaire

The questionnaire was presented in Bahasa Indonesia (Appendix 7.1). The translation of the questionnaire in English is shown in Appendix 7.2.

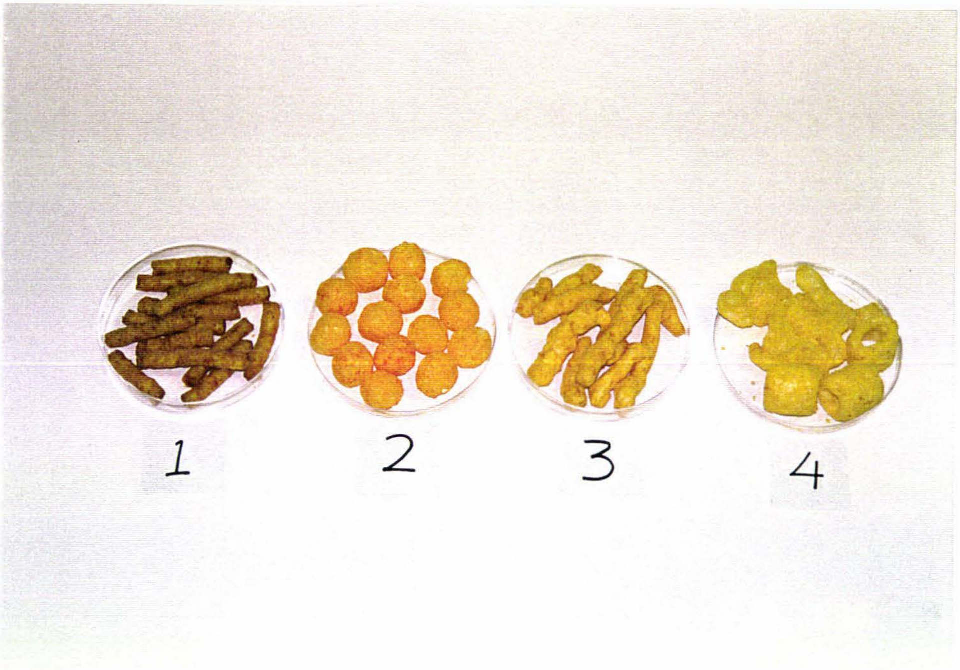


Figure 7.1 **Samples evaluated in the first section of the final product testing (1 = the developed product, 2 = *Chiki*, 3 = *Cheetos*, 4 = *Bigun*)**

The questionnaire consisted of two parts. The first section was a ranking test between the new product and commercial products. The second part enquired about the consumers' snack eating frequency, new extruded snack concept testing, new product testing, buying intentions and the demography details of the participants.

The questionnaire had both check list and open ended questions. Words in common usage were selected in the questionnaire in order to avoid any misunderstanding or confusion. The questionnaire was pre-tested with 12 Indonesian living in Palmerston North before it was used for the large consumer test.

7.2.4 Data processing and analysis of results

The questionnaires were checked by the author, before data processing was conducted. The data was tabulated. The data from the check list question was then analyzed using a chi-square (χ^2) test with Minitab 10.5. The panellist's answers for the open-ended questions and the responds were summarised and used to provide a better explanation in the results. The summary of results is shown in Appendix 7.3.

7.3 EVALUATION OF THE EXTRUDED SNACK CONCEPT BY CONSUMERS IN INDONESIA

The product in this project was developed using Indonesians living in Palmerston North. Even though these people have lived in Palmerston North only for less than 2 years, there exists the possibility that their food preference had gradually changed due to the change in living environment (Bell & Meiselman, 1995). Therefore, the snack product concept and important product characteristics previously determined in the preliminary study had to be reevaluated in the final product testing by the possible target consumers in Indonesia.

In addition, the concept of adding soy bean in the extruded snack product was new for the Indonesian market. Even though foods made from soya, such as fermented soya bean, soya sauce and soya bean curd/tofu are often consumed with rice in their daily diet, soya is not commonly eaten as a snack by the target market. There was a doubt whether the consumers could accept soya as their snack ingredients and as a healthy and nutritious source for food.

7.3.1 Acceptance of soy as an ingredient

72% consumers would consume the snack containing low fat soy bean, as soy bean was considered a good protein source, important for the daily diet (see Appendix 7.3 table for question 5). The concept of no cholesterol content in the new snack was also responded positively, in conjunction with a healthy image of food.

7.3.2 Frequency of snack consumption

Of the 147 targeted consumers, 104 people categorized themselves as extruded snack eaters (Table 7.1). 75% of the extruded snack eaters consumed snack products at least 2-3 times a month.

43 people claimed to be non-extruded snack eaters (Table 7.1). The reason for not eating extruded snack is because they assume that extruded snack are snacks for children. Some of them regarded extruded snack as an expensive item which is occasionally purchased/consumed. Most of this group (51%) consumed snack products less than once a month.

Table 7.1 Frequency of any snack products consumption by extruded snack eater and non extruded snack eater

Frequency	Extruded snack eater[1)] (people)	(%)	Non-extruded snack eater[1)] (people)	(%)	Total consumers[1)] (people)	(%)
More than or equal to 2 - 3 times a month	78	(75.0)	13	(30.2)	91	(61.9)
Less than once a month	19	(18.3)	22	(51.2)	41	(27.9)
Do not eat snack anymore	7	(6.7)	8	(18.6)	15	(10.2)
Total column	104	(100)	43	(100)	147	(100)

1) percentage were calculated from the total consumers on each group/column

7.3.3 Consumer expectation of extruded snack characteristics

The desired snack characteristics were investigated through a comparison with the properties of similar snack products which consumers were familiar with. Favourable and unfavourable characteristics were identified by the consumers as well as their most preferred commercial product.

As shown in Table 7.2, more than 60% of the consumers either on the extruded snack eater group or the non extruded snack eater group considered crispiness and flavour were the most favourable characteristics on the extruded snacks. This result supported the conclusion made in the consumer research at the preliminary stage of snack development (Chapter 3).

Even though the preliminary study was conducted using small groups of Indonesians living in Palmerston North, the information obtained contributed a useful guidance to the further stage of development (snack formulation). The information gathered from the focus group in the preliminary study provided good directions to the product developer about the important characteristics required to be available in

Table 7.2 Favourable characteristics expected by consumers

Favourable characteristics[1]	Number of consumers[2]				Total consumer[2]	
	extruded snack eater		non-extruded snack eater			
	(people)	(%)	(people)	(%)	(People)	(%)
Crispiness	96	(92.3)	28	(65.5)	124	(84.4)
Flavour	89	(85.6)	31	(72.1)	120	(81.6)
Shape	61	(58.7)	17	(39.5)	78	(53.1)
Low price	60	(57.7)	18	(41.9)	78	(53.1)
Colour	57	(54.8)	18	(41.9)	75	(51.0)
Hygiene/no nauseous effect after eating	53	(51.0)	16	(37.2)	69	(46.9)
Packaging design	48	(46.2)	14	(32.6)	62	(42.2)
Halal ingredients	49	(47.1)	12	(27.9)	61	(41.5)
Nutritional information	44	(42.3)	13	(30.2)	57	(38.8)
Familiarity with the product	23	(22.1)	9	(20.9)	32	(21.8)
Packet size	21	(20.2)	9	(20.9)	30	(20.4)
Others[3]	4	(3.9)	3	(7.0)	7	(4.8)
Total panellists on each group	104		43		147	

1) Characteristics were set according to the order of importance

2) Percentages were calculated from the total number of panellists in each group (e.g. 92.3% = 96/104); consumers could tick the characteristic options as many as they aimed.

3) included legalization approval, attractive advertising, no chemical additives and accessibility.

the extruded snack. It was interesting to know that although the Indonesians in Palmerston North have been exposed to the different living environment for less than 2 years, their expectation of extruded snack characteristics were still similar to the Indonesians living in Indonesia.

A small number of consumer (less than 10%) also mentioned that legislation approval, attractive advertising, no chemical additives and accessibility are expected characteristics of a snack food product. These characteristics were not considered essential to the consumers, although there was a tendency that consumers start giving more attentions to those characteristics.

Table 7.3 shows a list of products similar to the developed extruded product ranked by order of preference. The favourable characteristics were most probably found on the product brands of *Cheetos, Chiki* and *Taro* for the extruded snack eater and on the brand of *Cheetos*, as those brands were the ones they normally purchased. The extruded snack eater group purchased the snack more often than the non extruded snack eater, thus they had more variety of brand preference. However both groups agreed that *Cheetos* was the most preference brand, followed with *Chiki.*

Preferred flavours of these products are cheese, corn, chicken, chocolate, sea weed and barbecue. These preferred flavours information was obtained from their comments in answering the questionnaire.

Table 7.3. Snacks existing in the Indonesian market ranked by order of preference

Brands	Number of consumers				Total consumer[1) (people) (%)	
	Extruded snack eater[1) (people)	(%)	Non-extruded snack eater[1) (people)	(%)		
Cheetos	48	(46.2)	15	(34.9)	63	(42.9)
Chiki	47	(45.2)	6	(14.0)	53	(36.1)
Taro	29	(27.9)	3	(7.0)	32	(21.8)
Chitato	12	(11.5)	3	(7.0)	15	(10.2)
Jetz	10	(9.6)	2	(4.7)	12	(8.2)
Happy tos	5	(4.8)	3	(7.0)	8	(5.4)
Gizanda	4	(3.9)	0	(-)	4	(2.7)
Serena	2	(1.9)	0	(-)	2	(1.3)
Other brands	5	(4.8)	1	(2.3)	6	(4.1)
Total panellists on each group	104		43		147	

1) Percentages were calculated from the total number of panellists in each group (e.g. 46.2% = (48/104)*100)

Table 7.4 shows characteristics that the panellists considered unfavourable for an extruded snack ranked in order of importance. These unfavourable characteristics are summarised as: feeling thirsty after eating, sticky in the mouth, sticky on the hand while holding the snack, oily products and unfavourable flavour. Oily products were unpreferable characteristic as it produced greasy mouth-feel and greasy feeling on the hand when the snack was hold. In addition oily product could make the product appearance unattractive and did not appeal to be consumed. This results agreed with the result of product concept testing obtained at the preliminary study (Section 3.2) at which consumers indicated that the flavour and product texture were the important product attributes to be considered when consuming an extruded snack.

Table 7.4 Unfavourable characteristics found by consumers on snacks currently in the market

Unfavourable characteristics[1]	Number of consumers[2]				Total consumers[2] (people) (%)	
	Extruded snack eater (people)	(%)	Non-extruded snack eater (people)	(%)		
Feeling thirsty after eating	67	(64.4)	20	(46.5)	87	(59.2)
Sticky in the mouth	55	(52.3)	15	(34.9)	70	(47.6)
Sticky on the hand while holding	51	(49.0)	16	(37.2)	67	(45.6)
Product is oily	47	(45.2)	15	(34.9)	62	(42.2)
Unfavourable flavour	39	(37.5)	15	(34.9)	54	(36.7)
Colour	26	(25.0)	6	(14.0)	32	(21.8)
High price	26	(25.0)	4	(9.3)	30	(20.4)
Packaging	10	(9.6)	2	(4.7)	12	(8.2)
Others	5	(4.8)	2	(4.7)	7	(4.8)
Total panellists on each group	104		43		147	

[1] The characteristics are set according to order of importance
[2] Percentages were calculated from the total number of panellists in each group

7.4 CONSUMER ACCEPTABILITY OF THE NEW EXTRUDATE SNACK

In order to evaluate the acceptability of the developed snack, a consumer acceptability test was carried out with the 147 Indonesian panellists. A 7 points hedonic acceptability scale was used to evaluate product's colour, overall appearance, aroma, taste and overall preference.

Table 7.5 shows the weighted mean for each of the attributes considered. The table illustrates that the weighted mean score of the developed snack was within the range of 4 and 5, i.e. between like slightly and neither like nor dislike. Consumers commented that the product was too oily and stuck in the mouth. Both characteristics are considered unfavourable characteristics as described in section

7.4.2 (Table 7.4). This was a possible reason that the acceptability score was less than expected. A reduction of the oil used in the flavour application is suggested.

Table 7.5 Developed snack acceptability tested by itself

Acceptability	Weighted mean[1] (Σ(x.n)/total panellists)		Weighted sum[2] (Σ(x.n))	
	Extruded snack eater	Non-extruded snack eater	Extruded snack eater	Non-extruded snack eater
Colour	4.3	4.7	444	204
Overall appearance	4.5	4.9	468	211
Aroma	4.1	4.3	422	184
Taste	4.4	4.3	461	186
Overall preference	4.4	4.6	461	198

[1] [2] x = number of participants on each rank
n = factor for the degree of acceptability (n = 7 like very much; n = 1 dislike very much); higher value indicates higher acceptability

A number of panellists expressed that the sensation of the snack "melting" in the mouth is an important product attribute of a snack product. However this sensation could be the reason that the product was found too sticky. The glass transition temperature (Tg) of the product was found to be about 36°C (refer to Appendix 5.6). Product with higher glass transition temperatures value could overcome this unfavourable characteristic. However as shown in Chapter 5 high Tg value could result in products with higher breaking strengths which might affect their crispiness.

There were no significant differences on snack acceptability between consumers who claimed to be snack eaters or non-snack eaters. Both groups had a similar preference on the new snack product, although they were categorized themselves into two conserve snack eater groups.

7.5 COMPARISON WITH OTHER COMMERCIAL PRODUCTS

Comparison with other commercial snacks were carried out using blind tests. These tests compare the product preference, regardless of the marketing tools (package, brand, price and promotion).

Four samples were evaluated and ranked. The samples tested included the developed snack product, *Cheetos, Chiki* and *Bigun*. *Cheetos* was selected as it occupied the highest market place when the study was carried out. *Chiki* had occupied that place, before *Cheetos* was launched in the market. *Bigun* was one of the new extruded products available in the market.

Table 7.6 shows the weighted mean and sum on each sample for both the extruded snack eater and the non-extruded snack eater groups. *Cheetos* had the highest weighted sum in both groups, followed by *Chiki, Bigun* and/or equals to the new product, respectively.

Table 7.6 Results of the blind test to determine the snack preference (Products ranked by order of preference)

Samples[1)]	Weighted mean[2)] (Σ(x.n)/total panellists)		Weighted sum[2)] (Σ(x.n))	
	Extruded snack eater	Non- extruded snack eater	Extruded snack eater	Non-extruded snack eater
Cheetos	3.4	3.3	354	142
Chiki	2.3	2.3	240	101
Bigun	2.2	2.2	230	94
New product	2.1	2.2	216	93

1) Samples were coded with number and no brand name or information was given to the consumers

2) x = number of participants on each rank

n = factor for the preference rank (n = 4 the most preferred; n = 1 the least preferred). Higher value indicates higher preference

Overall the new product had a similar preference with *Bigun*, but it was less preferred than the other two samples, that is *Cheetos* and *Chiki*. The weighted mean for the new product and *Bigun* were similar within the non extruded snack eater group (2.2) while, within the extruded snack eater group, were 2.1 and 2.2, respectively. This indicates that both the new product and *Bigun* had a similar preference. Both products were not well-recognized by the consumers, so it is believed a fair judgement based only on the sensory attributes was obtained.

Even though samples were coded with number and no brand name or information was given to the consumers. The consumers could guess what the samples were from its appearance and taste. This could be explained that by the fact *Cheetos* and *Chiki* were very popular to the consumers and brand awareness is important in the snack market.

Another reason that the new extruded snack had a lower preference than *Cheetos* and *Chiki* could be due to the high oil content of the new product. High oil content reduced product palatability and therefore was less preferred. For this reason it is still required further development of the extrudate, particularly to reduce the oil content.

While the new product is acceptable when tested on its own, it may need to be improved to compete well with known favourites. It is impossible to conclude whether the new extruded snack was less preferred because the commercial products were easily recognized by the panellists.

7.6 CONSUMER PURCHASE INTENTION

About 61% (89 participants) of the consumers answered that they would buy the new product, if available in the market (P=0.25). Eighty four percent of these consumers would buy the product more than or equal to 2-3 times per month (Table 7.7).

Table 7.7 Buying frequency for the new product

Buying frequency	Number of consumers[1]				Total consumers[1]	
	extruded snack eater (people)	(%)	non-extruded snack eater (people)	(%)	(people)	(%)
More than or equal to 2 - 3 times a month	55	(79.7)	20	(100)	75	(84.3)
Once a month	4	(4.5)	0	(0.0)	4	(4.5)
Less than once a month	10	(11.2)	0	(0.0)	10	(11.2)
Total column	69	(100)	20	(100)	89	(100)

[1] percentage were calculated from the total consumers on each group/column

About 80% extruded snack eater group and all the non extruded snack eater group of the consumers, who answered that were going to buy the new product, would buy the product more than or equal to 2-3 times per month. This result is slightly too high as the consumer preference towards the developed snack was only slightly acceptable. It is highly unlikely that all snack food eater would swap their purchase to the new product. However this shows that the consumers response was positive and it could indicate a potential success of the new product in the Indonesian market.

The non-extruded snack eater group had higher tendency to purchase the new product. This result was encouraging as the new product may gain a new target market. The new product seemed to attract some of the non extruded snack eater group to be snack eaters. In the previous discussion (Table 7.1), 13 people from the non extruded snack eater group consumed any snack products more than 2-3 times per month. This number improved as shown in Table 7.7. Twenty people from the same group would buy the new product at the same frequency (more than or equal to 2-3 times per month).

This change in attitude could be the effect of the product concept. A healthy image of the new product built through the soy ingredient and familiarity to the other product ingredients, such corn and rice, convince the consumer that the new product was good for them.

7.7 PRICE AND PACKET SIZE OF THE NEW EXTRUDATE SNACK

Consumers who answered that they would buy the new product were asked for a suitable price and packet size for the new product. They were asked to consider in their evaluation the price and packet size compared with the price of the extrudate snack they are currently purchasing. The results of the recommended price and packet size by the consumers are shown in Tables 7.8 and 7.9, respectively.

Table 7.8 Price recommendation from consumers who answered that they would buy the product, when compared with similar product's price that they are currently purchasing

Recommended price	Number of consumers[1]				Total consumers[1] (people) (%)	
	extruded snack eater (people) (%)		non-extruded snack eater (people) (%)			
Slightly higher/same	34	(49.3)	16	(80.0)	50	(56.1)
Slightly lower	28	(40.6)	4	(20.0)	32	(36.0)
Very much lower	7	(10.1)	0	(0.0)	7	(7.9)
Total	69	(100)	20	(100)	89	(100)

[1] percentage were calculated from the total consumers on each group/column

As shown in Table 7.8, about 56% of the consumers in both groups that were willing to buy the developed product were prepared to pay a slightly higher price than the same product that they are currently purchasing (about Rp.350/20g). About 36% of the consumers wanted the product to be sold at a slightly lower price than that they currently buy.

Table 7.9 Packet size recommended by the consumers who were willing to buy the product, in comparison with similar product packets that they are currently purchasing

Packet size (in each packet)	Number of consumers[1)]				Total consumers[1)] (people) (%)	
	extruded snack eater (people)	(%)	non-extruded snack eater (people)	(%)		
20 - 25 g	40	(58.0%)	13	(65%)	53	(59.6%)
45 - 50 g	13	(18.8%)	4	(20%)	17	(19.1%)
More than 70 g	13	(18.8%)	1	(5%)	14	(15.7%)
Others (in bulk)	3	(4.4%)	2	(10%)	5	(5.6%)
Total	69	(100%)	20	(100%)	89	(100%)

1) percentage were calculated from the total consumers on each group/column

There were no significant difference (P=0.7) in the packet size preference for the new product by both groups. Table 7.9. shows that a small packet size (20-25 g) is more preferable than a bigger one (more than 70 g/packet). About 6% of the consumers suggested the new product could be sold in bulk, as they assumed buying in bulk would decrease the product cost as less package cost has to be paid.

7.8 CONCLUSION

The concept of adding low fat soy bean to the extruded snack product was widely accepted by both extruded snack consumer and non-extruded snack consumer groups. The panellists accepted the concept of adding low fat soy bean which they felt it could increase the product nutritional value, particularly the protein content. Moreover, this concept affected their purchase intention; the new product was intended to be purchased as frequently as more than or equal to 2-3 times a month if the price of the product was similar to the price of the products currently purchased.

The product concept indeed had a large effect on the non-extruded snack consumer group. The consumer testing showed that it is more likely that the non-extruded snack eater group can become an extruded snack eater group.

Since there were no significant difference in product acceptability and purchase intention between the two consumer groups, it can be concluded that the market segment of the new product would include both the extruded and non-extruded snack eater groups. The new product could be positioned as a substitute to the snacks they are currently consuming with a nutritional supplement value.

The developed snack had a similar preference to the new commercial sample (*Bigun*). In order to improve the chance of success in the market, the acceptability of the developed snack could be improved by reducing both the oil used in the flavour coating and its stickiness.

Even though the product was only perceived as slightly acceptable, the consumer would buy the snack at the price and packet size similar to the snacks that they currently consume. Therefore, it could be considered worthwhile producing the snack in a commercial scale, once the improvements were done and retested.

It is also suggested that a market test of the product should be conducted before the product is launched in the market in order to assess other factors (packaging, advertisement and brand name) which could affect consumers' buying decision and to predict the market share. The developed product was different from the extruded snack in the market in terms of its nutritional image, crispiness, product appearance and main ingredients.

COMPARISON BETWEEN SINGLE AND TWIN SCREW EXTRUDERS FOR THE MANUFACTURE OF THE SNACK PRODUCT

8.1. INTRODUCTION

Single and twin screw extruders are used in the food industry for the manufacture of snack products. It is recognized that twin screw extruders are, at expenses of their higher costs, more flexible and versatile to produce a large variety of products. The main differences between single and twin screw extruders including working principle, capital and operating costs, and potentiality in product development have been discussed elsewhere (Harper, 1979) and will not be described here.

During the snack development in this project, it was found that twin screw technology is very versatile and several variables could be adjusted to control the physical and sensory properties of the product. However, the cost of twin screw extruder is a very limiting factor in their use, as small companies cannot afford the large investment that their purchase would involve.

Therefore the main objective of this study was to study the feasibility of using a single screw extruder to manufacture a similar product than that manufactured with the twin screw extruder. Specific objectives were:

- to investigate the differences on functional and physical properties of extrudates' produced by single screw and twin screw extruders.
- to evaluate the product preference between snacks produced by single screw and twin screw extruders.

8.2 SINGLE SCREW EXTRUDATE STUDY

In order to compare the performance of single and twin screw extruders, a similar formulation was used in this study. The formulation used is described in Table 8.1. This formulation is the same as formulation 5 which was used to produce the product used in the large scale consumer test.

Table 8.1 Ingredients for formulation 5 (consumer test formulation)

Raw materials	Proportion (%)
Corn meal	59.6
Defatted soya flour	28
Rice flour	12
Baking soda	0.4

8.2.1 Experimental conditions used on the single screw extruder

The experiments on the single screw extruder were run at constant screw speed and temperature. As the extruder used was a low shear type machine, the screw speed was set very high (860 rpm) as an attempt to produce shear rates comparable to that applied with the twin screw extruder. The barrel temperature was controlled in 2 zones. The first zone was set of 80°C, while the second zone was set at 170°C.

Feed rate and moisture feed were the variables adjusted in this study. The feed rate was adjusted in a range of 10-17.9 kg/hr (300 - 550 rpm), while the moisture of the ingredients mixture was adjusted to 15% - 16%. The process conditions used are shown in Appendix 8.1.

For comparison only extrudates produced with the twin screw extruder, feed moisture of 16% and various process condition were considered. These runs are shown in Appendix 8.2.

8.2.2 Extrudates analysis

8.2.2.1 *Functional and physical properties analysis*

The extrudates were analyzed for moisture content (MC), Water Absorption Index (WAI), Water Solubility Index (WSI), Nitrogen Solubility Index (NSI), Specific Mechanical Energy (SME) and Glass Transition Temperature (Tg). The methods of analysis were described in sections 4.3.2.1, except SME described in section 4.5. The colour and texture (breaking strength) measurements were also carried out following the procedures explained on section 4.3.2.2.

The effect of feed rate and moisture feed on the parameters MC, WAI, WSI, NSI, Tg, breaking strength and colour measurement were statistically analyzed using a two way-analysis of variance (ANOVA). A t-test was used to find the differences between extrudate characteristics produced with both twin screw and single screw extruders.

8.2.2.2 *Sensory evaluation*

The difference between single screw and twin screw extrudate produced was also studied through sensory evaluation. A seven point hedonic acceptability scale test and a *just right* scale test described in section 4.4.4 and 4.4.6 were applied, respectively. The seven point hedonic acceptability scale test was carried out to determine the preference on flavour, texture, colour and overall appearance, while the *just right* scale test was employed to identify the degree of crispiness of the samples.

Texture was the most noticeable sensory characteristic difference between single screw and twin screw extrudates. The single screw extrudate was found much harder than the twin screw extrudate. Therefore the extrudate with the lowest breaking strength was selected to represent the single screw extrudate in the comparison study (Table 8.2). This sample was an extrudate produced with a feed rate of 11.38 kg/hr and a moisture feed of 15.37% (coded S_1).

Table 8.2 Different extrudate texture

Single screw extrudate	Breaking strength (N)	Twin screw extrudate	Breaking strength (N)
S_1	10.2	T_1	4.15
S_2	11.0	T_2	5.47
S_3	11.6	T_3	3.30
S_4	12.4	T_4	4.05
S_5	13.1		
S_6	14.7		

The twin screw extruder product used for the large scale consumer test was used as the representative of the twin screw extrudate (coded T_4 in Appendix 8.2.).

The samples were coated with Ethnican spicy flavour (QZ 02346) supplied by Quest International following the sample preparation described on section 5.2.2.1. Thirty three panellists participated in this evaluation and the questionnaire used is shown in Appendix 8.3.

8.3 RESULT: SINGLE SCREW EXTRUDATE CHARACTERISTICS

Table 8.3 shows functional and physical properties of extrudates prepared with various feed rate and feed moisture. Table 8.4 gives F-values to study the effect of feed moisture and feed rate determined by ANOVA.

Table 8.3 Analysis on functional and physical properties of single screw extrudate

Trial Code	Variable		MC (%w/w)	WAI	WSI (%)	NSI (%)	SME (~W.hr/kg)	Tg (°C)	BS (N)	Colour			
	Feed rate (kg/hr)	Feed moisture (%w/w)								L^*	a^*	b^*	ΔE^*
S_1	11.38	15.37	8.30	4.32	14.2	9.72	52.6	64.71	10.20 ± 1.88	76.25	1.72	32.91	37.1
S_2	13.01	15.37	8.24	4.36	13.1	9.80	46.0	89.02	11.01 ± 3.75	77.47	0.76	32.35	35.9
S_3	17.89	15.37	8.89	4.05	12.2	11.15	33.5	94.02	11.62 ± 2.48	77.26	1.17	32.01	35.8
S_4	11.38	16.23	9.55	4.84	13.2	9.97	44.7	90.16	12.38 ± 1.77	77.18	1.53	30.68	34.7
S_5	13.01	16.23	9.38	4.29	13.5	9.05	42.5	93.98	13.10 ± 1.13	75.73	2.29	31.68	36.5
S_6	17.89	16.23	9.85	4.01	12.5	9.72	30.9	94.05	14.68 ± 1.15	75.55	2.13	31.60	36.4

Note : MC = Moisture content
WAI = Water Absorption Index
WSI = Water Solubility Index
NSI = Nitrogen Solubility Index
SME = Specific Mechanical Energy
Tg = Glass Transition Temperature
BS = Breaking strength

Table 8.4 **F-values to study the effect of variables (ingredients moisture and feed rate) on the physical and functional properties of extrudates using ANOVA**

Variable	MC	WAI	WSI	NSI	Tg	BS	Colour			
							L^*	a^*	b^*	ΔE^*
Feed moisture	59.9***	9.2**	0.01	6.9**	19.2***	27.1***	14.6***	391.9***	18.6***	8.7**
Feed rate	4.1*	28.8***	5.4*	2.3	18.1***	4.4**	0.7	4.2**	0.4	1.3
(Feed moisture * Feed rate)	0.6	8.1**	3.3*	3.2	10.2**	1.3	16.2***	169.5***	4.5**	57.1***

Note : * 0.05 < P ≤ 0.1
** 0.01 < P ≤ 0.05
*** P ≤ 0.01

MC = Moisture content
WAI = Water Absorption Index
WSI = Water Solubility Index
NSI = Nitrogen Solubility Index
SME = Specific Mechanical Energy
Tg = Glass Transition Temperature
BS = Breaking strength

8.3.1 Effect of feed moisture and feed rate on single screw extrudate characteristics

As indicated by the F-values given in Table 8.4, feed moisture and feed rate affect most of the extrudate characteristics. The feed moisture significantly affected all the measured parameters MC, WAI, NSI, Tg, BS, L^*, a^*, b^* and ΔE^* with exception of WSI. Parameters MC, WAI, WSI, Tg, BS and a^* value were affected by feed rate. In addition as shown in Table 8.4, the interaction between feed moisture and feed rate affected WAI, WSI, Tg, L^*, a^*, b^* and ΔE^* values.

It is obvious that when the feed moisture is high, extrudate with higher moisture is produced. The study showed the WAI and NSI were significantly affected by the moisture feed ($P<0.01$). The effect on WAI is due to the starch fragmentation. When starch breaks into fragments is transformed to molecules that absorbs more water (Wen *et al.*, 1990). Thus, the increase in feed moisture in the limited moisture environment increased the water abortion. Maximum fragmentation occurs at limited feed moisture, low temperature and high screw speed (Wen *et al.*, 1990; Senouci & Smith, 1986) or at limited feed moisture and high temperature (Williams *et al.*, 1977).

There was no significant effect of processing conditions on WSI. This result agrees with extrusion of corn starch by Owusu-Ansah *et al.* (1983). Only little effect on WSI was found at feed moisture of about 20%.

The insolubilization of protein due to the presence of moisture and high temperatures was clearly explained by Angemier & Montgomery (1976). In the presence of water the hydrophillic groups react through hydrogen bonds with the protein. The interaction between disulphide during protein denaturation also require moisture for the transition reaction.

Products with higher BS and Tg were obtained by increasing feed moisture. Although it has been recognized that high moisture favours gelatinization, the feed moisture also reduces the viscosity of the melt, decreasing internal friction and heat dissipation during the process. This results in less degradation of the starch molecules, less expanded and harder products. Lai & Kokini (1991) explained this extrusion behaviour at high moisture content.

Feed rate on the single screw extruder had a negative effect on the physical and functional properties of extrudate (WAI, WSI, Tg and BS). The reason for this is not very clear but since the single screw extruder operation depends on the friction between the product and the barrel, an increase in feed rate could cause an increase pressure in the extruder, increasing slippage at the barrel surface. This decreases the shear applied to the product resulting in less starch degradation.

A combination between the feed rate and the feed moisture of variables also affected the physical properties of the extrudate. The moisture in this situation acts as a plasticiser for the starch polymers (Guy, 1994), reducing its viscosity and friction during the process.

The extrudate's colour was also affected during the process, due to the changes in the ingredient properties.

8.3.2 Relationship between Specific Mechanical Energy (SME), Glass Transition Temperature (Tg) and Breaking Strength (BS)

As indicated in Figures 8.1, 8.2 and 8.3 the relationships between Breaking Strength (BS), Specific Mechanical Energy (SME) and Glass Transition Temperature (Tg) appear to exhibit similar trend than those obtained with the twin screw extrudates. Figure 8.1 shows that BS decreased with SME. Similarly, as illustrated in Figure 8.2, Tg decreased with increases in SME.

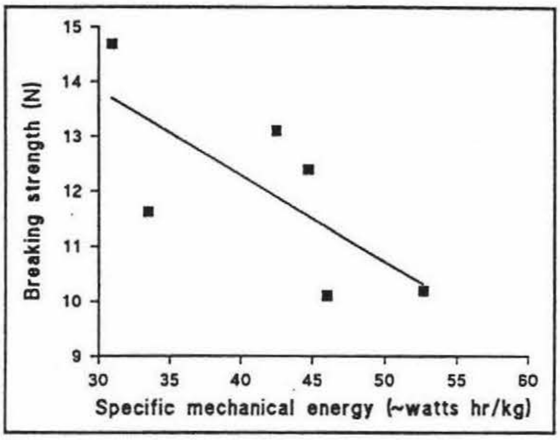


Figure 8.1 Correlation between breaking strength (BS) and SME

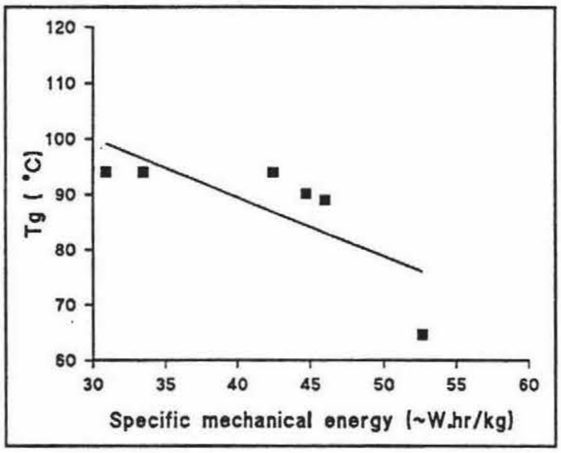


Figure 8.2 Correlation between Tg and SME

Mechanical energy breakdowns polymers (mainly starch) producing compounds of lower molecular weights than the original polymers (Kaletunc & Breslauer, 1993). The extrudate formed with these lower molecular weight compounds requires less breaking strength (break easily) and exhibit lower glass transition temperatures as shown by Kaletunc & Breslauer (1993). This is illustrated in Figure 8.3 which shows a positive correlation between glass transition and breaking strength. This correlation could probable be used in a commercial situation to determine conditions to produce snacks with appropriate textures.

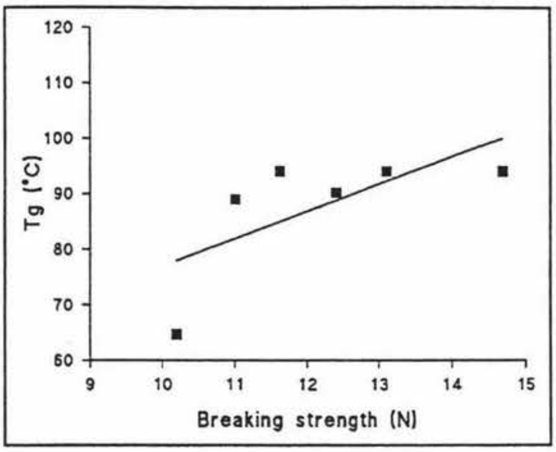


Figure 8.3 Correlation between BS and Tg

8.4 COMPARISON OF EXTRUDATE CHARACTERISTICS PRODUCED WITH SINGLE AND TWIN SCREW EXTRUDERS

Table 8.5 shows the characteristics of extrudates produced with the single screw extruder and the twin screw extruder.

As indicated in Table 8.5, a t-value analysis shows significant difference in most of parameters (MC, WSI, NSI, Tg, BS, L^*, a^*, b^* and ΔE^*), suggesting that the resulting product functional characteristics are different. The mechanical energy of the single screw extruder was not considered as it was not possible to determine the conversion factor between the extruder motor current and torque.

The input of mechanical energy during extrusion produces a number of chemical reactions on the raw materials, particularly starch conversion. It has a major impact on biopolymer molecules through shear effect, although a great deal of mechanical energy is also converted to thermal energy (Kokini, 1993).

Table 8.5 Snack characteristics produced on single screw and twin screw extruders

Trial Code[1]	MC (%w/w)	WAI	WSI (%)	NSI (%)	SME (W.hr/kg)	Tg (°C)	BS (N)	Colour			
								L^*	a^*	b^*	ΔE^*
S_4	9.55	4.84	13.2	9.97	44.7~	90.16	12.38 ± 1.77	77.2	1.58	25.5	34.7
S_5	9.38	4.29	13.5	9.05	42.5~	93.98	13.10 ± 1.13	75,4	2.28	31.7	36.5
S_6	9.85	4.01	12.5	9.72	30.9~	94.05	14.68 ± 1.15	75.6	2.08	31.6	36.4
T_1	6.90	4.42	31.2	22.0	195	37.9	4.15 ± 0.68	70.1	4.88	27.6	37.5
T_2	10.22	5.18	15.3	14.5	132	42.4	5.47 ± 1.17	72.8	7.66	31.9	38.6
T_3	6.32	4.61	32.0	18.8	176	41.1	3.30 ± 0.24	66.9	10.96	26.6	39.5
T_4	7.27	4.03	26.3	17.6	196	36.0	4.05 ± 1.33	67.5	10.76	26.0	40.3
t-value[2]	3.33**	-0.81	-5.03***	-7.88***	--	32.83***	11.73***	-4.19***	3.25**	1.87*	-3.74***

Note : * $0.05 < P \leq 0.1$

** $0.01 < P \leq 0.05$

*** $P \leq 0.01$

1) the mean value from the analysis result

2) t-test analysis

MC = Moisture content

WAI = Water Absorption Index

WSI = Water Solubility Index

NSI = Nitrogen Solubility Index

SME = Specific Mechanical Energy

Tg = Glass Transition Temperature

BS = Breaking strength

Results show that the single screw extruder produced harder extrudates (with larger breaking strength) and higher glass transition temperatures (Tg) than those produced with the twin screw extruder. The higher breaking strength and higher Tg values are related to the availability of macromolecules in the extrudate. In the single screw extruder, the shear produced was lower than that produced in the twin screw extruder, resulting in less molecular degradation. The moisture content (MC) of single screw extrudates tended to be higher. Also the lower water solubility obtained with single screw extrudates (WSI) clearly indicates lower molecular degradation during the single screw extrusion process.

The comparison study showed there was no significant difference on WAI. This was perhaps related to the starch degradation under limited moisture conditions. During degradation, starch transforms into fragments with smaller molecule sizes. The fragmentation in both single screw and twin screw extrudates appears similar as both produced fragmented starch with the same ability to absorb water.

On the other hand, WSI results showed that higher starch degradation occurred during the twin screw extrusion process, as measured for the ability of these degraded compounds to solubilize in water. Extrusion of corn grits has shown that when WAI is plotted versus WSI, the graph forms of an inverted U shaped curve (Kirby *et al.*, 1988). This supports the fact that similar WAI values could occur at different stage of starch degradation. The experiments carried out during the project seem to indicate that single screw extrudates have not reached the peak level of starch fragmentation whereas twin screw extrudates exceeded the maximum WAI versus WSI curve.

NSI measurements were significant difference between the two extrusion processes. Nitrogen solubility index on the single screw extrudate was lower than that of the twin screw extrudate. Although higher screw speeds were used in single screw extrusion process, results clearly showed that the shear level on the twin screw extruder was considerably higher and affected the protein solubilization in a larger extent than the single screw extruder. This result is somewhat surprising as it was expected that more severe shear in the single screw extruder will impair protein solubility.

There were significant difference in L^*, a^*, b^* and ΔE^* colour values. The single screw extrudate was found to be lighter than the twin screw extrudate. Increases in screw speed in the single screw extruder lowers the residence time which associated to the low shear applied in the single screw extruder could result in products with less browning reaction and thus less dark products.

8.5 COMPARISON OF PRODUCT PREFERENCE BETWEEN SINGLE SCREW AND TWIN SCREW EXTRUDATES

Untrained panellists evaluated the colour, overall appearance, texture, flavour and overall acceptability of single screw (S_1) and twin screw extrudates (T_4) using a 7 hedonic scale. They also assessed the extrudate crispiness using a *just right* scale of 5 points.

Table 8.6 shows that the twin screw extrudate had a significant higher acceptance ($P<0.01$) on texture, flavour and overall preference than the single screw extrudate. There was no significant difference in colour and overall appearance between twin screw extrudate and single screw extrudate, although the twin screw extrudate appeared to have a slightly higher score in preference. The samples of both twin and single screw extrudates is shown in Figure 8.4.

The result of the *just right* test shown in Table 8.6 also indicates that the twin screw extruder produced a snack product with a more acceptable crispiness than the single screw extruder. The details of panellists' respond are shown in Appendix 8.4.

Table 8.6 Comparison snack preference and crispiness between single screw and twin screw extrudates

Sensory evaluation	Parameter	Mean score		t-value[d)]
		TSE[c)]	SSE[c)]	
Preference test[a)]	Overall preference	1.91 ± 0.46	2.58 ± 2.00	-2.4***
	Flavour	1.73 ± 1.08	2.82 ± 2.34	-3.4***
	Texture	2.06 ± 0.93	2.91 ± 2.59	-2.6***
	Colour	2.09 ± 0.96	2.24 ± 1.89	-0.6
	Overall appearance	2.18 ± 0.90	2.30 ± 0.72	-0.6
Just right test[b)]	Crispiness	2.76 ± 0.31	3.24 ± 1.69	-2.0**

** $0.01 < P \leq 0.05$
*** $P \leq 0.01$
a) A lower mean indicates a higher preference score (1 = like very much; 7 = dislike very much)
b) A lower mean indicates a higher degree of crispiness (1 = much too crispy; 5 = not crispy enough)
c) TSE = Twin screw extrudate; SSE = Single screw extrudate
d) obtained from t-test

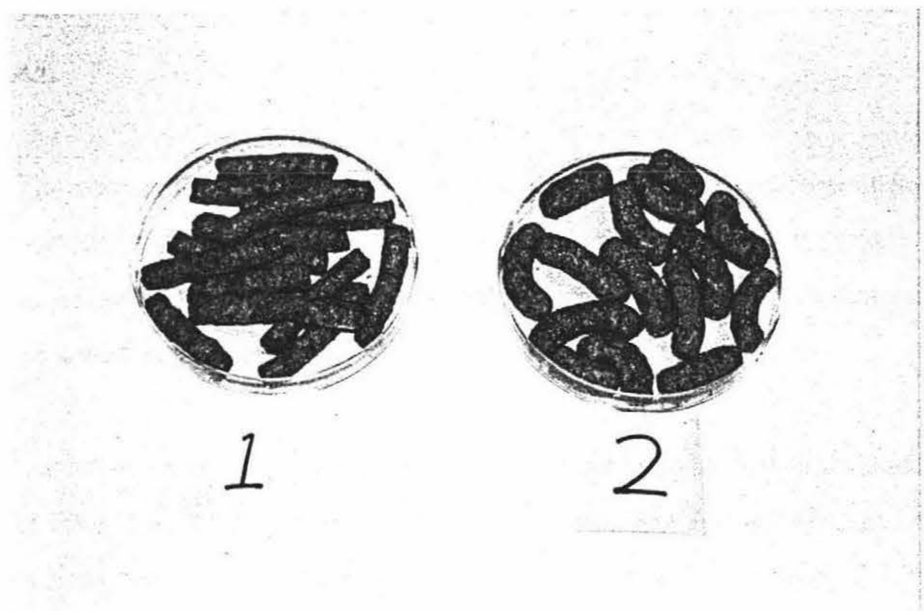


Figure 8.4 Samples manufactured using twin screw extruder (1) and single screw extruder (2)

The twin screw extrudate was more acceptable than the single screw extrudate. This indicates that the twin screw extrudate provided a better palatability. The twin screw product also exhibited better acceptability when flavour was assessed.

The better palatability could be the result of higher shear applied in the twin screw process. Although the samples were coated with the same flavouring agent (Ethnican flavour), it appeared that the base snack had a favourable flavour resulting from the extrusion process.

The twin screw extrudate had higher Water Solubility Index (WSI) and lower Glass Transition Temperatures (Tg) than the single screw extrudate. Lower Tg and higher WSI values indicate more starch breakdown into small molecules (Nelson & Labuza, 1993; Kaletunc & Breslauer, 1993; Tan & Chinnaswamy, 1993). These small molecules possible dissolved faster in the presence of saliva and the snack flavour could be tasted better. On the other hand, larger molecules do not dissolve easily, keeping the snack structure and given a grainy or sandy sensation when consumed.

The panellist responses about the single screw extrudates (Table 8.6) show a large variation with the mean score between 2 and 3 (like moderately and like slightly). This indicated that there were an important number of panellists who like the single screw extrudate.

Tables 8.7 and 8.8 show a cross tabulation between texture preference (based on the hedonic scale) and results from the *just right* scale for single screw extruder and twin screw extruder, respectively. Similar Tabulations containing the raw data are shown in Appendix 8.5. The tables indicate the relationship between the degree of crispiness obtained from *just right* scale and the snack texture preference obtained from the hedonic scale test.

Table 8.7 Relationship between degree of crispiness (*just right* test) and texture preference (hedonic test) for snacks produced with the single screw extruder

Panellists on each hedonic and *just right* scale		Texture preference on each hedonic scale[b] (%)							Total row
		1	2	3	4	5	6	7	
	1	-	3.0	3.0	-	3.0	3.0	-	12.1
Just right	2	6.1	6.1	6.1	-	-	-	-	18.2
scale[a] (%)	3	12.1	3.0	3.0	-	-	-	3.0	21.2
	4	3.0	6.1	18.2	-	3.0	-	-	**30.3**
	5	-	3.0	3.0	6.1	3.0	3.0	-	18.2
Total column		21.2	21.2	**33.3**	6.1	9.1	6.1	3.0	100

a) indicates degree of crispiness (1 = much too crispy; 3 = just right; 5 = not crispy enough)

b) indicates degree of texture preference (1 = like very much; 4 = neither like or dislike; 7 = dislike very much)

Table 8.8 Relationship between degree of crispiness (*just right* test) and texture preference (hedonic test) for snacks produced with the twin screw extruder

Panellists on each hedonic and *just right* scale		Texture preference on each hedonic scale[b] (%)							Total row
		1	2	3	4	5	6	7	
	1	-	3.0	-	-	-	-	-	3.0
Just right	2	6.1	-	9.1	6.1	-	-	-	21.3
scale[a] (%)	3	27.3	33.3	9.1	3.0	-	-	-	**72.7**
	4	-	-	3.0	-	-	-	-	3.0
	5	-	-	-	-	-	-	-	-
Total column		**33.3**	**36.4**	21.2	9.1	-	-	-	100

a) indicates degree of crispiness (1 = much too crispy; 3 = just right; 5 = not crispy enough)

b) indicates degree of texture preference (1 = like very much; 4 = neither like or dislike; 7 = dislike very much)

For the single screw extrudate (Table 8.7), the highest percentage (33.3%) on texture preference (hedonic test) was on the scale three (like slightly) and on the *just right* scale (30.3%) was on scale four (slightly too little crispiness). This relationship could indicate the texture was less preferred as it was less crispy.

Conversely, Table 8.8 shows that the texture of twin screw extrudate was highly preferred. A 33.3% of the panellists like the texture very much (scale 1 on the hedonic scale test) and 36.4% panellists like it moderately (scale 2 on hedonic scale). The degree of crispiness of the twin screw extrudate was "just right" to the panellist's taste (72.7%). Thus, it could be concluded that the twin screw extrudate crispiness was very close to that of the panellists preference.

Results of the *just right* scale for the single screw extrudate were very scattered (Table 8.7). The fact that the single screw extrudate was hard and produced loud sound when chewing gave various interpretation of the degree of crispiness. Some panellists claimed that the snack was not crispy enough (score 5) as its texture was hard while some claimed the snack was much too crispy (score 1) as it produced too loud chewing sound. If another *just right* crispiness test were run, it would be necessary to define the term crispiness to the panellists, to differentiate the judgement due to the product crispiness from the sound produced when chewing.

8.6 CONCLUSION

Feed moisture, feed rate and interaction between feed moisture and feed rate significantly affected the properties of single screw extrudates. The increased feed moisture produced extrudate with higher moisture. Under the limited moisture environment used in this process, the increase in feed moisture accelerated the starch fragmentation and protein insolubilization. However, extrudate functional properties (WAI, BS, Tg, NSI) showed that the extent of starch degradation and protein denaturation was lower in single screw extrusion than in twin screw extrusion.

The trends obtained between measured physical characteristics (Tg vs SME and BS vs SME) were similar to those obtained with the twin screw extrudates. Higher SME produced snacks formed with smaller molecular size compounds, as indicated by the lower Tg and breaking strength measured values.

The different operational conditions applied on the single screw and twin screw extrusion process produced snacks with different physical and sensory characteristics. The twin screw extruder applied higher shear than the single screw extruder, thus affecting the starch degradation in larger extent than the single screw extruder. The interaction between rice and soya could be the reason that the protein solubility in the twin screw extrusion resulted higher than the single screw extrusion.

A comparison between the sensory properties resulted that the twin screw extrudate was more preferred than the single screw extrudate. The snack was crispier and the texture suited more the panellists preference. The flavour was also more enhanced.

Although the twin screw extrudate had a higher preference than the single screw extrudate, there is an indication that some panellists also liked the single screw extrudate. Further study is suggested to investigate the potential segment market for this product.

In order to improve the properties of single screw extrudate to be closer to the characteristics of twin screw extrudate, the use of bigger corn grit particle size is suggested. It has been found that larger particle size improve the single screw extrusion process (Ostrowskyj, 1996, personal communication). It is also suggested that a higher shear single screw extruder should be tested to improve extrudate crispiness.

OVERALL DISCUSSION AND RECOMMENDATIONS

9.1 INTRODUCTION

The research carried out in this project was aimed in producing an acceptable coextruded snack food for the Indonesia market using NZ corn grits, defatted soya flour and other Indonesian raw materials, notably rice and tapioca. Consumers were directly involved in the development process and the final snack product developed was considered acceptable by the consumers. The developed snack was also comparable to the commercial products in terms of sensory attributes.

9.2 OVERALL DISCUSSION AND CONCLUSIONS

9.2.1 Market opportunity for extruded snack in Indonesia

Results of this study indicated that there is an opportunity for success for a new-western style snack food (extruded snack) in Indonesia. The slow movement in consumer demand, from the traditional to western types of foods, promotes this success. Important product attributes (crispiness & flavour) and product awareness is the key success for a snack product in the Indonesian snack market.

The developed product differed from snacks already in the market in terms of nutritional image, crispiness, product appearance and main ingredients. The addition of soya gave an image of a nutritious snack to the consumer, while the addition of rice was believed to make the snack crispier. The product was considered more nutritious and attracted the target market (adults over 18 years old) who were either snack eater or non-snack eater groups.

9.2.2 Application of a Design Experimental Software (Echip) in this study

The experimental design software used for the snack basic formulation (Echip) was found applicable for the product formulation process. Echip enabled the combination of processing condition and ingredient variables.

The process conditions and ingredients were treated as two different types of variables. Process conditions were defined within a given range, while ingredients were defined as proportions. Many product developer in the commercial industries, the optimum processing conditions and ingredient proportions are obtained separately through several "trial and error" experiments or other experimental design methods. Therefore using Echip can reduce the time requirement during the development process.

During this project it was observed that both process conditions and ingredient proportions affected the extrudate properties. A small change in the processing conditions dramatically changed the extrudate properties. Therefore a design which could combine both type of variables (processing variables and ingredient proportions) was preferred.

The design showed the existing relationships between functional properties (MC, WAI, WSI and NSI); physical properties (BS, L^*, a^* and b^* value) and consumer acceptability with processing conditions and ingredient variables. The consumer acceptability of the extruded snack base in this formulation was correlated with rice content, soya content and T4 (temperature of the fourth barrel). Therefore these variables could be used to predict consumer acceptability of the snack base.

The experimental designs obtained from Echip in this project produced 31 different formulations combined with various process conditions. For the product development research, these designs gave satisfactory results that enable the optimization of the formulation with a minimum amount of trials.

When the results of the 31 trials were analyzed as a whole there was a large variability between results. This large variability was anticipated as the 31 samples were obtained from different formulations and process conditions. Even though there was a large variability in overall results, when each formulation was analyzed alone, the results were as expected with a dramatic decrease in variability.

9.2.3 Selection of extrusion cooking as an alternative process for snack manufacture

This study demonstrated the successful use of extrusion in the production of a snack for the Indonesian market. The process provided versatility and improved the low value of the raw materials.

Either single or twin screw extruders could be used in the snack manufacture using the selected formulation, although the twin screw extrudate produced a snack with high preference. However, if investment cost is a constraint, the single screw extruder still can be used.

Most of the experiments in this project were done using a twin screw extruder, due to the availability of the equipment. The comparison study with the single screw extruder performance was only done in a very short time (2 weeks). With more time available, a detailed design product optimization would be necessary, particularly by altering the formulation (such as using corn grits with a bigger particle size and increasing the proportion of rice flour) and process conditions (such temperature alterations and preconditioning to the temperature adjustment before being extruded) in order to obtain a product with properties similar to the twin screw extrudate but with a lower production cost.

The study showed that physical properties and sensory attributes of the products should both be considered in order to obtain optimum snack formulations. It is recommended that physical properties measurements be carried out with sensory evaluation during the optimization of the product formulation. If a suitable physical analysis is obtained and correlated with a sensory attribute, then it could sustain the product quality and limit the human error occurring in the sensory test.

9.2.4 Feasibility of In-house testing in extruded snack development

In-house test was selected to evaluate the snack base formulation, as it allowed the panellists to set their own testing time, in which the panellists were more motivated in testing the product. The evaluation was basically to obtain the most acceptable extruded snack base and took 3-5 days.

As the snack base formulations produced from the experimental design was excessive (31 samples) to be evaluated once, they were separated into six groups of samples and tested in different sections. It was almost impossible to ask the participants to volunteer the sensory test and come to the central location six times continuously. The participants might reluctantly test the products, thus the results might not reflect their true attitude.

In-house testing implies a more realistic environment condition than a central location testing, although the attitude towards snack acceptability could be influenced by other family member's opinions. For a snack product this constraint was accepted as the snack was tended to be consumed when a group of people is gathered.

In this type of test, the panellists were required to prepare the samples by themselves following the instruction given by the researcher. Clear and simple instructions for sample preparation are necessary as the panellists can be consumers who comes from various background and different knowledge. The evaluation for the snack produced in this study did not require any sample preparation, except a glass of water to rinse the mouth before testing each sample. The samples were coded in plastic bags and grouped randomly. The panellists only were required to pick a plastic bag randomly and do the evaluation.

Overall, in-house test was found to be applicable for this development study. The panellists had a better motivation in testing and a large number of samples could be tested in a relatively short period of time. In-house test is recommended to be used when samples do not require a very complicated preparation. However in-house test has the disadvantage of a large variability of data response, particularly the rating questions (Moskowitz, 1994).

9.2.5 The use of consumer (untrained) panellists over trained panellists in this study

Consumer panellists were used in this study in order to obtain an extruded product that was accepted by the target consumers. Despite a large variability in the consumers' response, the selection of consumer panellists would be expected to give a better prediction of the product preference than trained panellists as they represent the potential target consumers.

Trained panellists could give a better correlation between an objective physical property, such as breaking strength and a sensory characteristic such as crispiness. However they could not explain the range of crispiness that the consumer may prefer. According to Moskowitz (1983) the acceptability follows an inverted U shaped curve when plotted against the proportion of an ingredient or against a sensory characteristic. This means there is an optimum acceptability on a certain breaking strength load which could only be detected by the consumer panellists.

Nevertheless for a comparison study, it is suggested to investigate further the convenience of the use of consumer panellists or trained panellists to establish a correlation of sensory properties with objective physical properties of the extruded snack product.

9.3 RECOMMENDATIONS FOR FURTHER STUDY

The developed snack was found worthwhile to be developed further in a commercial scale either using a twin screw extruder or a single screw extruder, depending on the available equipment. A product market test should be conducted before the product is launched on the market in order to test other factors (price, packaging, brand name and advertising) which may affect consumer's buying decision apart from the sensory attributes. In that market test, it should be necessary to assess the influence of the competitors' products on consumer buying decision when the product is put side with them. A market share should also be estimated through the market test.

Further studies on single screw extrusion are suggested in order to obtain a more similar product with that produced with the twin screw extruder with a lower production cost. The study should include an optimization of process conditions and ingredient formulations.

The study found that there was a general trend between the snack sensory attributes, particularly texture and colour, and the extrusion process. This correlation should be investigated further in order to have a better definition of the most acceptable product characteristics that could be obtained. The product developer could then alter the ingredients and processing conditions in order to obtain the extrudate's texture and colour that the consumers may most prefer.

In-house testing is an alternative to evaluate a product with the target consumers, however it was recommended to do a comparison study between in-house and central location testing for a snack product so that a more affirmative suggestion could be made in selecting the testing location.

This study showed that the extrusion process affected the main chemical component properties of the raw materials with reactions, such as starch degradation and protein denaturation. However, the mechanism of these transformations was not explained thoroughly. It is suggested that measurements which can quantify these transformations such as degree of starch gelatinization and starch dextrinization be carried out, in order to have a better explanation about the extrusion effects on the raw material main components.

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Appendix 3.1 Questionnaire format used in the focus group discussion. Preliminary consumer study of expanded snack

Part I.

QUESTIONNAIRE

Name : Date :

Please answer the following question:

1. Which of the following corn snacks have you ever consumed ?*)

( ) Corn extruded snack
( ) Corn chips
( ) Pop corn
( ) Others, please specify___________________

*) Note:
- Extrusion snack is made by cooking raw materials, such as corn and water in a extruder machine, using high temperature, high pressure and short time.
- Corn chips is made by frying the mixture of raw materials, such as corn and water.

2. The following items are the types of flavour available in the market :

- Cheese flavour - Roasted corn - Paprika
- Chicken flavour - Soya sauce - Potato
- Barbecue - Salsa - Caramel
- Teriyaki - Bacon - Chocolate
- Sea weed - Mexican spicy

Please list the flavours you most prefer
(1 = the most preferable; 5 = the least preferable)

1. ______________
2. ______________
3. ______________
4. ______________
5. ______________

3. How often do you consume the corn extruded snack ?

( ) More than 4 times a week
( ) 2 - 4 times a week
( ) Once a week
( ) 2 - 3 times a month
( ) Less than once a month

Appendix 3.1 (Cont.) Questionnaire format used in the focus group discussion. Preliminary consumer study of expanded snack

Part II.

Name :   Date :

The three types of products which you received are samples of commercial extruded snacks available on the market. Please observe their appearance and taste them, before answering the questions

1. Please list the characteristics that are important to you when you buy an extruded snack

2. Please list the characteristics that are important to you, when you eat an extruded snack

3. Do you like those snack ? What do you suggest those snacks can be made from ?

Snack 1:(   )

Snack 2:(   )

Snack 3:(   )

4. Please rank the following characteristics that are important to you when you consume an extruded snack (1 = the most important; 10 = the least important)

(   ) uniformity in size
(   ) uniformity in shape
(   ) colour
(   ) flavour
(   ) crispiness (using incisors for the first bite)
(   ) crunchiness (using molars for chewing)
(   ) crumbliness (the deformation of snack in the mouth into pieces)
(   ) product melting in the mouth
(   ) adhesiveness of mass (degree to which mass sticks to the roof of the mouth or teeth)
(   ) Tooth packing (product left and stuck in molars)

Appendix 3.1 (Cont.) **Questionnaire format used in the focus group discussion. Preliminary consumer study of expanded snack**

5. Please rank the following characteristics that are important to you when you buy an extruded snack (1 = the most important; 9 = the least important)

( ) price
( ) package size
( ) brand
( ) accessibility
( ) flavour
( ) appearance of package
( ) familiarity with the product (have tried the product before)
( ) occasion of consumption
( ) ingredients list

> An extruded snack is developed at Massey University. This snack is made from corn, defatted soya bean, tapioca and rice flour. The product will be marketed in Indonesia and have several advantages over other products in the market.
>
> The product will have a higher protein content, due to the presence of soya bean. Defatted soya bean is a type of plant protein source, which has a high content of protein, low fat and no cholesterol. Because of the addition of tapioca and rice flour in the snack ingredients, the product will become more crispy and crunchy. In addition, tapioca and rice flour make the snack expand bigger and lighter.

6. Would you eat an extruded snack product including soya bean ?

( ) Yes ( ) No

Please give the reasons:

____
____

7. If the snack described above are available in the market, will you buy it?

( ) Yes ( ) No

Comments:

____
____
____

8. Would you buy this snack product in preference to the product you presently eat ?

( ) Yes ( ) No

Please give the reasons:

Product	Reasons

Appendix 3.1 (Cont.) Questionnaire format used in the focus group discussion. Preliminary consumer study of expanded snack

9. What occasion will you prefer to consume that snack product ?
For hints: during lunch time, while watching TV/cinema, during leisure time, social gathering, party, picnic, etc

____

____

____

____

Thank you for your cooperation

Appendix 3.2 Important characteristics considered when purchasing an extruded snack

Product attributes	Participants on degree of importance[+)]									Σ(x.n)[-)]	Total Z Values[*)]
	1	2	3	4	5	6	7	8	9		
Price	3	2	4	4	2	-	3	1	3	119	1.06(3)
Package size	-	1	3	2	6	7	1	2	-	106	-0.56(6)
Brand	2	1	1	2	3	3	5	3	2	95	-1.85(8)
Accessibility	3	2	2	4	2	-	3	3	3	109	-0.13(5)
Flavour	4	9	2	2	3	1	1	-	-	156	7.68(1)
Package appearance	3	-	2	-	4	3	5	3	2	96	-1.54(7)
Familiarity with the product	4	5	3	4	-	-	-	5	1	132	2.79(2)
Occasion of consumption	-	-	3	1	-	5	2	4	7	68	-7.43(9)
Ingredients list	3	2	2	3	2	3	2	1	4	109	-0.01(4)

Note : +) Degree of importance (1 = the most important; 9 = the least important)
-) x = number of participants on each rank
n = factor for the degree of importance
(n = 9 for the most important; n = 1 for the least important)
*) Related to importance proportion (Thurston case V)
Number in the bracket indicates the degree of importance for each product attribute

Appendix 3.3 Important characteristics considered when consuming an extruded snack

Product attributes	Participants on degree of importance+)										Σ(x.n)-)	Total Z Values*)
	1	2	3	4	5	6	7	8	9	10		
Uniformity in size	-	1	4	5	3	3	1	2	3	-	125	0.22(5)
Uniformity in shape	-	4	-	3	3	5	4	-	1	2	120	-0.08(6)
Colour	1	1	4	3	4	3	2	2	1	1	128	0.79(4)
Flavour	18	1	1	-	-	-	1	-	-	-	203	12.46(1)
Crispiness	1	11	2	2	2	3	-	-	-	1	167	6.69(2)
Crunchiness	-	2	7	4	7	1	1	-	-	-	153	5.15(3)
Crumbliness	-	-	2	4	-	3	7	5	-	1	103	-2.97(7)
Product melting in the mouth	-	1	-	1	2	2	4	8	4	-	86	-5.26(8)
Adhesiveness of mass	1	-	-	-	2	2	-	4	4	9	61	-8.73(10)
Tooth packing	-	1	2	-	-	-	2	1	7	9	59	-8.28(9)

Note : +) Degree of importance (1 = the most important; 10 = the least important)
-) x = number of participants on each rank
n = factor for the degree of importance (n = 10 for the most important; n = 1 for the least important)
*) Related to importance proportion (Thurston case-V)
Number in the bracket indicates the degree of importance for each product attribute

Appendix 3.4 Familiarity with corn snacks

Types of corn snacks	Participants (people)	(%)
Corn extruded snacks	22	(100)
Corn chips	19	(86.4)
Pop corn	20	(90.9)
Others (roasted corn, boiled corn)	3	(18.2)
Number of panellists	22	

Appendix 3.5 Occasions to consume the snack product

Occasion	Participants (people)	(%)
While watching TV	16	(72.7)
During a leisure time	16	(72.7)
Picnic	14	(63.6)
Social gathering	8	(36.4)
Party	8	(36.4)
Meals	3	(13.6)
During studying	2	(9.1)
While reading books	2	(9.1)
While I feel like to eat something	1	(4.6)
Before bed time	1	(4.6)
When I see someone eating that product	1	(4.6)

Appendix 4.1 Preliminary production trials

Several preliminary trials were carried out before the actual snack development experiment. These trials were aimed to obtain the range of feasible ingredients in the experimental design and to set the range of feasible process conditions. This preliminary work was also aimed in developing analysis method for extrudates assessment.

Different formulations were prepared using combinations of different raw materia, such as corn meal, defatted soya flour, rice flour, tapioca flour and baking soda. The proportion of corn meal was expected to be more than 50%. Simple ingredient combinations, containing two or three ingredients were prepared at the beginning of trials to investigate the raw material effects on extrudate characteristics. Table A4.1 shows the preliminary trials

The range of feasible process condition was obtained from trial and error runs. High shear rate and temperature are required to produce a direct expanded snack (Jones, 1995, personal communication). High shear rate could be produced using high screw speed or low moisture feed rate.

Table A4.1 Preliminary trials

Trial	Formulation proportion (%)					Process							
	Rice flour	Tapioca flour	Defatted soya flour	Corn meal	Bak. soda	Feed (rpm)	Water (L/hr)	Screw (rpm)	T1 (°C)	T2 (°C)	T3 (°C)	T4 (°C)	Torque (N.m)
1.1	30	-	-	70	-	0.52	0.38	258	37	68	155	181	24.7
1.2	30	-	-	70	-	0.51	0.38	304	47	96	159	180	24.3
2.1	30	-	-	69	1	0.52	0.40	269	41	79	156	180	24.8
2.2	30	-	-	69	1	0.51	0.40	304	37	81	151	180	24.1
3.1	30	-	-	70	-	0.40	0.28	336	40	76	115	154	18.1
3.2	30	-	-	70	-	0.57	0.28	364	39	79	115	161	16.1
4.1	30	-	-	69.6	0.4	0.57	0.28	339	41	80	117	160	18.1
4.2	30	-	-	69.6	0.4	0.58	0.28	297	38	80	117	159	20.3
4.3	30	-	-	69.6	0.4	0.58	0.28	325	30	79	153	120	22
5.1	-	30	-	70	-	0.58	0.27	409	40	80	124	141	15.9
5.2	-	30	-	70	-	0.58	0.28	336	38	80	118	158	13.3
5.3	-	30	-	70	-	0.58	0.31	329	40	80	117	150	20
5.4	-	30	-	70	-	0.58	0.31	297	38	79	118	149	20
5.5	-	30	-	70	-	0.58	0.30	297	38	79	120	155	15.5

Cont...

Table A4.1 (Cont.) Preliminary trials

Trial	Formulation proportion (%)					Process							
	Rice flour	Tapioca flour	Defatted soya flour	Corn meal	Bak. soda	Feed (rpm)	Water (L/hr)	Screw (rpm)	T1 (°C)	T2 (°C)	T3 (°C)	T4 (°C)	Torque (N.m)
6.1	20	0	20	59.6	0.4	0.55	0.2	330	37	80	116	160	25.2
6.2	20	0	20	59.6	0.4	0.55	0.2	330	36	80	116	141	26.1
7.1	0	10	28	61.6	0.4	0.55	0.15	300	40	80	116	161	24.3
7.2	0	10	28	61.6	0.4	0.55	0.2	300	38	80	115	140	27.5
8.1	20	5	10	64.6	0.4	0.56	0.24	300	40	80	115	156	18
8.2	20	5	10	64.6	0.4	0.55	0.17	311	42	80	115	156	26.3
8.3	20	5	10	64.6	0.4	0.55	0.17	307	42	80	116	146	24.8
9.1	20	5	15	59.6	0.4	0.54	0.17	314	43	80	116	146	28.8
9.2	20	5	15	59.6	0.4	0.55	0.17	315	39	79	116	140	29.8
10.1	20	10	10	59.6	0.4	0.56	0.17	315	46	80	114	140	27
10.2	20	10	10	59.6	0.4	0.55	0.17	330	46	80	116	140	25

Trial 1 - 2 failed as the corn meal had a large size to produce a direct expanded snack. Some of the corn was not cooked/melted and the texture was hard. The different particle distributions of corn grits used in the preliminary trials are shown in Table A4.2.

Table A4.2 Size distribution of corn meal used in preliminary trials

Preliminary trials	Percentage on each particle size (%)						
	850µ	600µ	425µ	300µ	150µ	75µ	<75µ
Trial 1 and Trial 2	76.09	11.34	7.13	13.25	13.07	1.84	0.06
Trial 3 - Trial 10	0.55	3.8	40.06	27.69	23.24	4.44	0.15

The presence of baking soda in the formulation gave a more uniform and smaller air cell size distribution in the extrudate. Figure A4.1 illustrates structure of extrudates produced with and without baking soda.

Without baking soda Baking soda added

Figure A4.1 Diagram of extrudate's structure

The addition of tapioca until 30% (Trial 5) caused an undesirable extrudate stickiness. Trial 7 and 10 using 10% of tapioca flour in the formulation produced a very high torque (25-27 N.m) which caused extruder blockage. Thus 10% tapioca was considered the upper tapioca limit in the formulation.

A similar phenomena occurred when 20% rice flour combined with defatted soya flour added to the formulation. The torque became 24-30 N.m. The torque should not exceed 30 N.m, as the extruder would automatically shut down for safety reasons. Thus a range 2-20% of rice flour was set for the optimization. Rice flour was expected to improve the snack texture.

A large amount of defatted soya flour produced an extrudate with brownish colour. Furthermore, 28% defatted soya flour in the formulation gave burnt flavour at high temperature (Trial 7.1). Therefore 28% was set as the upper limit for the soya flour. 10% was set as the lower limit as defatted soya flour in order to have a high protein snack product.

Screw speed, water addition and temperature at the fourth barrel were set as the parameters. Screw speed and water addition affected the shear rate during the process, while temperature at the fourth barrel affected the extrudate cooking and expansion. The screw speed was varied between 250-410 rpm in preliminary trials. The speed between 300-330 rpm would be used in the actual experiment. The pumped water and the temperature at the fourth barrel were set between 0.15-0.2 litre/hr and 140-160°C, respectively.

Analysis methods were developed during the preliminary experiments to analyze the extrudates. Most of the analysis methods were standard methods. For texture measurement, an Instron Universal Testing machine was used. Maximum compression load was applied for the texture measurement at the first and second trials, however the breaking strength was selected as the parameter as it gave a better indication of the extrudates' texture. The results of the extrudates' analysis are shown in Table A4.3

Table A4.3 Analysis of extrudates produced during the preliminary trials

Trials	Moisture content (%)	WAI	WSI (%)	NSI (%)	Instron - Texture measurement	Colour measurement				Comments
						L^*	a^*	b^*	ΔE^*	
1.1	13.5	6.07	12.1	12.2	76.1	78.6	-3.92	38.3	40.6	Texture was hard, some of the corn was not
1.2	14.0	5.15	15.5	14.2	76.0	76.9	-3.62	37.1	40.3	cooked/expanded.
2.1	13.6	5.64	11.6	12.0	76.6	79.5	-1.86	43.6	44.8	Baking soda gave better air cell size
2.2	13.9	6.29	25.6	12.0	53.9	80.1	-1.61	44.1	45.0	distribution.
3.1	14.9	4.89	8.35	7.8	18.3	80.6	-4.43	43.7	44.6	Extrudates expanded well, but the
3.2	11.7	4.75	6.59	10.0	38.8	78.0	-6.93	38.3	40.9	cutter did not cut well.
4.1	10.6	9.68	9.25	9.42	41.0	78.7	-1.80	40.7	42.5	The product was too sticky.
4.2	11.3	7.92	9.08	8.51	28.0	78.9	-1.92	42.4	44.0	30% tapioca in the formulation was not
4.3	13.8	6.90	7.86	1.70	21.5	80.2	-3.53	44.6	45.5	feasible, the machine shut as the torque was excessive.
5.1	13.8	4.15	22.2	16.5	47.3	77.5	-3.93	41.6	44.0	Addition of soya in the formulation gave a
5.2	13.4	3.44	21.9	11.4	33.8	79.7	-4.01	43.1	44.3	brown colour.
5.3	9.4	3.21	13.5	27.0	19.2	77.9	-1.35	39.6	41.9	The air cell sizes were small.
5.4	10.3	3.06	10.3	21.1	15.7	75.9	-0.64	40.0	43.2	
5.5	9.7	2.81	11.2	13.8	18.7	72.7	-0.65	36.1	41.8	
6.1	6.3	5.04	27.2	19.6	4.10	69.8	3.44	27.8	38.0	Extrudate was crispy.
6.2	6.9	4.81	19.8	21.5	4.36	71.6	2.68	29.8	38.0	
7.1	6.5	4.48	21.8	17.0	3.22	68.9	4.18	26.8	38.0	Burnt flavour, the colour was too dark.
7.2	6.4	4.60	39.5	17.7	3.40	68.2	3.94	27.9	39.1	Snack was crispy.

Cont...

Table A4.3 (Cont.) Analysis of extrudates produced during the preliminary trials

Trials	Moisture content (%)	WAI	WSI (%)	NSI (%)	Instron - Texture measurement	Colour measurement				Comments
						L^*	a^*	b^*	ΔE^*	
8.1	10.3	6.25	12.0	8.24	7.26	76.3	-0.54	37.2	40.7	Air cell size was bigger than the one made in trial 5.
8.2	6.57	5.40	20.9	13.9	5.02	72.9	1.95	31.1	37.9	
8.3	6.68	5.57	29.7	13.2	3.96	72.6	2.00	30.6	37.7	
9.1	6.70	4.85	21.2	13.1	2.99	72.4	2.27	29.6	37.1	Lower temperature gave less brown colour (visually). The torque was high (28-30 N.m)
9.2	6.65	6.63	15.1	13.7	3.24	72.5	2.25	29.3	36.9	
10.1	6.68	5.53	16.1	15.0	2.96	73.4	1.62	30.9	37.4	The torque was high (25-27 N.m).
10.2	6.55	4.78	24.2	16.1	2.54	72.4	2.53	30.1	37.6	

Appendix 5.1 Experimental conditions for the 31 trials (based on the experimental design)

Ingredients	Trial code[a)]	Formulation proportion (%)					Process							
		Rice	Soya	Tapioca	Corn	Bak. soda	Feed (kg/hr)	Water (L/hr)	Screw (rpm)	T1 (°C)	T2 (°C)	T3 (°C)	T4 (°C)	Torque (N.m)
Formula 1	1A	20	10	10	59.6	0.4	4.39	0.15	300	41	80	112	140	27
	1B	20	10	10	59.6	0.4	4.31	0.15	300	40	80	114	139	26.9
	2A	20	10	10	59.6	0.4	4.39	0.17	307	40	80	114	160	24.3
	2B	20	10	10	59.6	0.4	4.31	0.2	300	40	80	116	160	24.3
	3A	20	10	10	59.6	0.4	4.31	0.2	332	42	80	115	140	22.5
	3B	20	10	10	59.6	0.4	4.39	0.2	332	37	80	114	140	24
	4A	20	10	10	59.6	0.4	4.39	0.15	329	36	80	116	160	21.8
	4B	20	10	10	59.6	0.4	4.39	0.15	329	37	80	114	160	22
	24	20	10	10	59.6	0.4	4.31	0.15	315	37	80	114	160	21.1
	25	20	10	10	59.6	0.4	4.31	0.17	300	40	80	115	161	25.3
	26	20	10	10	59.6	0.4	4.39	0.15	300	39	80	116	152	25.5
Formula 2	9	20	20	0	59.6	0.4	4.39	0.15	300	38	80	116	160	24.8
	10	20	20	0	59.6	0.4	4.39	0.2	332	37	80	116	160	24
	12	20	20	0	59.6	0.4	4.39	0.2	301	36	80	116	141	27
Formula 3	5A	2	28	10	59.6	0.4	4.47	0.16	300	39	75	114	160	22.3
	5B	2	28	10	59.6	0.4	4.31	0.15	301	38	80	116	161	25
	6	2	28	10	59.6	0.4	4.39	0.12	329	37	75	114	160	21.5
	7	2	28	10	59.6	0.4	4.47	0.2	300	40	80	116	138	27.4
	11	2	28	10	59.6	0.4	4.47	0.15	332	39	80	116	139	25.8
Formula 4	14	7	28	5	59.6	0.4	4.47	0.2	336	41	80	114	140	27.4
	16	7	28	5	59.6	0.4	4.55	0.16	332	42	80	114	161	23
	17	7	28	5	59.6	0.4	4.39	0.15	300	40	80	114	140	28

[a)] Code A & B indicates replicates

Cont....

Appendix 5.1 (cont.) Experimental conditions for the 31 trials (based on the experimental design)

Ingredients	Trial code	Formulation proportion (%)					Process							
		Rice	Soya	Tapioca	Corn	Bak. soda	Feed (kg/hr)	Water (L/hr)	Screw (rpm)	T1 (°C)	T2 (°C)	T3 (°C)	T4 (°C)	Torque (N.m)
Formula 5	8	12	28	0	59.6	0.4	4.39	0.16	332	39	80	114	139	24.6
	13	12	28	0	59.6	0.4	4.55	0.20	301	40	75	116	160	19
	19	12	28	0	59.6	0.4	4.47	0.17	332	42	80	116	161	22.6
	22	12	28	0	59.6	0.4	4.47	0.15	304	40	80	113	140	27.5
Formula 6	15	20	15	5	59.6	0.4	4.47	0.15	332	42	80	113	141	24.9
	23	20	15	5	59.6	0.4	4.47	0.17	315	37	80	116	150	24.7
Formula 7	18	11	19	10	59.6	0.4	4.39	0.16	332	40	79	116	147	24.4
	20	11	19	10	59.6	0.4	4.31	0.2	315	40	80	117	161	24
	21	11	19	10	59.6	0.4	4.31	0.17	332	38	80	116	140	24.6

Appendix 5.2 Ingredients particle size distribution

Ingredients	Weight on each particle size (%)							Formulation proportion	Comments[a)]
	850μ	600μ	425μ	300μ	150μ	75μ	<75μ	(%)	
Corn	1.7	3.1	30.1	34.8	26.1	4.7	0.5	-	Variety 3162
Formula 1	0.5	1.5	12.9	15.7	19.6	16.3	33.5	Rice : soya : tapioca : corn : bak. soda = 20 : 10 : 10 : 59.6 : 0.4	Trial 1, 2, 3, 4, 24, 25
Formula 2	0.5	1.5	14.6	17.7	18.0	15.3	32.4	Rice : soya : corn : bak. soda = 20 : 20 : 59.6 : 0.4	Trial 9, 10, 12
Formula 3	0.9	2.2	15.3	16.8	17.3	11.6	35.9	Rice : soya : tapioca : corn : bak. soda = 2 : 28 : 10 : 59.6 : 0.4	Trial 5, 6, 7, 11
Formula 4	0.6	1.5	13.3	16.3	18.3	13.7	36.3	Rice : soya : tapioca : corn : bak. soda = 7 : 28 : 5 : 59.6 : 0.4	Trial 14, 16, 17
Formula 5	0.8	1.6	15.6	17.4	16.5	14.4	33.7	Rice : soya : corn : bak. soda = 12 : 28 : 59.6 : 0.4	Trial 8, 13, 19, 22
Formula 6	0.6	2.2	16.2	20.5	18.2	13.4	28.9	Rice : soya : tapioca : corn : bak. soda = 20 : 15 : 5 : 59.6 : 0.4	Trial 15, 23
Formula 7	0.7	2.0	15.4	21.2	18.8	11.5	30.4	Rice : soya : tapioca : corn : bak. soda = 11 : 19 : 10 : 59.6 : 0.4	Trial 18, 20, 21

[a)] the code of trials related to the design (Appendix 5.1)

Appendix 5.3 Analysis of functional properties of ingredients mixtures

Ingredients	MC (%)	WAI	WSI (%)	NSI (%)	Process condition (Trial code)[a]	Formulation proportion (%)
Formula 1	13.97	2.00	4.61	41.71	Trial 1, 2, 3, 4, 24, 25	Rice : soya : tapioca : corn : bak. soda = 20 : 10 : 10 : 59.6 : 0.4
Formula 2	13.64	2.04	7.42	56.45	Trial 9, 10, 12	Rice : soya : corn : bak. soda = 20 : 20 : 59.6 : 0.4
Formula 3	13.65	2.10	9.98	52.14	Trial 5, 6, 7, 11	Rice : soya : tapioca : corn : bak. soda = 2 : 28 : 10 : 59.6 : 0.4
Formula 4	13.39	1.99	9.83	48.99	Trial 14, 16, 17	Rice : soya : tapioca : corn : bak. soda = 7 : 28 : 5 : 59.6 : 0.4
Formula 5	13.48	2.05	9.68	42.68	Trial 8, 13, 19, 22	Rice : soya : corn : bak. soda = 12 : 28 : 59.6 : 0.4
Formula 6	13.85	1.95	6.04	48.22	Trial 15, 23	Rice : soya : tapioca : corn : bak. soda = 20 : 15 : 5 : 59.6 : 0.4
Formula 7	13.89	1.96	7.22	44.90	Trial 18, 20, 21	Rice : soya : tapioca : corn : bak. soda = 11 : 19 : 10 : 59.6 : 0.4

Note : MC = Moisture content (%wb)
WAI = Water absorption index
WSI = Water solubility index (%)
NSI = Nitrogen solubility index (%)

[a] the detail of the trial conditions is shown in Appendix 5.1

Appendix 5.4 Format of general testing information and questionnaire sheet

GENERAL INFORMATION

1. You received 6 big packets which each contains 5-6 types of samples/snack products and a questionnaire. (The samples in each packet were placed in the random order, thus you may receive them in the different orders from others).

2. Please test the products in each big packet on each time and ensure that you have a break (at least 30 minutes) before you continue to the next packet. You may like to set your own testing time as you are provided 3 days to test all the samples.

3. <u>Hints while testing</u>
Serve yourself with a glass of tap/plain water to rinse your mouth before testing each sample.

PRODUCT ACCEPTANCE TEST

Date : ....
Name : ....

Please mark the product codes at the position on the line that best reflects your attitude about the expanded extrusion snack and give comments.
Please ensure you rinse your mouth with plain water, before testing each sample.

Example : Acceptability :

132 456 721

Dislike extremely Like extremely

1. Overall, how do you feel about these snack products ?

Not acceptable Acceptable

Comments :

Thank you for your cooperation

Appendix 5.5 Randomized samples code for acceptability test

Sample No.	Panellist number														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	629	747	485	919	138	256	371	747	526	191	658	826	848	427	371
2	461	371	911	826	284	164	921	284	128	135	371	194	138	911	485
3	191	658	526	792	272	826	194	187	388	461	848	272	461	194	972
4	138	848	695	848	848	485	116	921	187	427	526	187	826	272	164
5	128	194	194	911	427	792	164	333	461	194	138	695	191	128	848
6	658	919	747	427	485	194	388	848	194	388	972	919	792	284	911
7	388	256	163	485	747	116	272	138	284	695	317	921	388	747	427
8	792	461	826	695	792	333	333	911	256	284	187	256	747	388	526
9	919	921	164	256	658	128	792	629	747	256	256	427	116	461	272
10	256	826	128	138	128	272	135	658	972	163	116	138	526	191	695
11	187	116	317	164	695	461	911	371	485	526	284	911	187	919	921
12	284	128	333	388	187	317	317	128	427	317	826	116	919	138	658
13	826	138	388	163	194	191	658	526	163	792	461	163	317	485	138
14	135	388	921	191	371	629	695	116	629	128	272	526	911	164	128
15	194	333	919	747	333	135	826	256	272	371	427	792	658	371	919
16	485	163	461	284	256	526	461	317	848	116	919	388	695	658	792
17	848	317	848	461	911	695	138	826	911	333	163	164	194	848	163
18	163	272	135	116	526	187	526	191	695	911	191	371	284	629	629
19	371	191	116	921	317	972	187	919	138	826	485	333	972	163	317
20	333	485	427	658	388	848	284	194	919	921	792	135	333	187	135
21	164	187	792	526	461	921	747	792	191	629	194	461	163	256	187
22	747	164	658	272	972	371	128	972	333	919	695	972	164	826	284
23	921	695	371	187	921	427	485	272	164	658	747	747	485	921	461
24	116	427	272	317	164	284	256	135	792	972	629	848	629	135	256
25	526	972	972	629	919	658	919	427	826	272	388	191	921	116	826
26	695	792	191	333	826	163	427	461	135	187	128	629	135	695	333
27	972	135	138	371	163	919	163	695	658	848	911	658	371	972	194
28	911	911	284	972	135	138	848	164	371	164	921	128	427	317	747
29	427	284	629	128	116	911	191	163	116	485	135	317	272	792	388
30	317	526	256	135	191	747	629	388	317	138	133	485	128	526	191
31	272	629	187	194	629	388	972	485	921	747	164	284	256	333	116
Panellist's name															

Note: 116 = trial 1A; 747 = trial 1B; 138 = trial 2A; 919 = trial 2B; 848 = trial 3A; 333 = trial 3B; 135 = trial 4A; 272 = trial 4B; 187 = trial 5A; 658 = trial 5B; 317 = trial 6; 284 = trial 7; 629 = trial 8; 695 = trial 9; 826 = trial 10; 388 = trial 11; 921 = trial 12; 371 = trial 13; 128 = trial 14; 972 = trial 15; 163 = trial 16; 911 = trial 17; 427 = trial 18; 164 = trial 19; 461 = trial 20; 191 = trial 21; 792 = trial 22; 256 = trial 23; 194 = trial 24; 526 = trial 25; 485 = trial 26

Appendix 5.5 (cont.) Randomized samples code for acceptability test

Sample No.	Panellist Number														
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	284	921	116	427	135	191	194	427	461	695	317	747	272	135	388
2	388	187	128	284	284	284	284	272	164	164	461	194	485	284	427
3	921	792	485	848	695	194	427	919	371	461	135	972	461	371	792
4	911	826	194	138	972	135	116	163	128	138	848	848	848	187	919
5	629	848	695	658	256	187	128	388	921	333	272	333	792	333	138
6	371	284	826	526	919	921	333	526	333	194	695	164	388	194	135
7	972	164	919	629	461	388	388	921	388	163	427	163	526	695	848
8	317	272	427	164	629	911	826	792	163	911	163	919	972	792	317
9	919	658	191	461	921	371	187	187	427	135	629	371	164	658	921
10	272	629	256	163	317	629	972	485	911	747	333	256	138	164	194
11	128	461	272	747	163	747	317	848	138	972	792	187	163	919	284
12	526	138	792	371	371	317	919	695	972	826	116	526	194	485	116
13	461	317	138	191	427	485	164	256	256	919	911	485	921	629	826
14	848	371	135	128	164	919	629	333	792	629	747	695	135	191	747
15	427	427	164	333	128	138	658	461	187	526	284	911	658	256	371
16	163	695	333	826	826	164	138	194	317	848	658	388	317	427	911
17	695	972	187	972	911	427	695	629	629	371	256	658	256	747	272
18	792	333	848	116	658	116	526	138	695	191	919	629	695	388	333
19	187	911	629	921	792	163	135	371	284	921	164	138	128	826	164
20	191	747	461	272	191	526	848	826	135	792	526	792	191	461	629
21	333	485	747	695	187	461	163	658	747	317	191	427	911	116	256
22	658	256	284	187	388	792	461	911	526	116	138	128	919	972	972
23	485	919	972	135	194	695	747	284	194	388	371	191	747	138	128
24	135	191	317	792	526	658	921	128	658	187	128	284	333	526	526
25	747	116	163	256	272	256	272	317	919	128	485	272	116	921	191
26	826	526	911	388	116	272	256	191	191	485	826	921	629	163	461
27	116	135	388	485	848	128	485	164	485	284	921	317	826	848	163
28	256	163	658	911	747	848	371	747	116	658	388	461	427	272	695
29	194	128	526	919	333	333	792	972	848	272	194	116	187	128	485
30	164	194	371	194	138	826	191	116	826	427	972	135	284	317	658
31	138	388	921	317	485	972	911	135	272	256	187	826	371	911	187
Panellist's name															

Note: 116 = trial 1A; 747 = trial 1B; 138 = trial 2A; 919 = trial 2B; 848 = trial 3A; 333 = trial 3B; 135 = trial 4A; 272 = trial 4B; 187 = trial 5A; 658 = trial 5B; 317 = trial 6; 284 = trial 7; 629 = trial 8; 695 = trial 9; 826 = trial 10; 388 = trial 11; 921 = trial 12; 371 = trial 13; 128 = trial 14; 972 = trial 15; 163 = trial 16; 911 = trial 17; 427 = trial 18; 164 = trial 19; 461 = trial 20; 191 = trial 21; 792 = trial 22; 256 = trial 23; 194 = trial 24; 526 = trial 25; 485 = trial 26

Appendix 5.6 Ratio on line scale acceptability test for snack base formulation

Formulation	Trial code	Product code	Ratio on line scale acceptability test on each panellist										Total
			1	2	3	4	5	6	7	8	9	10	
Formulation 1	1A	116	1.6	2.5	5.0	1.2	2.4	6.7	1.8	5.2	8.8	4.1	39.3
	1B	747	2.9	3.5	4.1	1.1	1.7	8.6	2.0	5.9	1.1	4.7	35.6
	2A	138	2.1	1.9	3.5	1.2	1.2	6.3	2.4	4.2	3.4	3.0	29.2
	2B	919	4.9	1.7	5.2	4.9	2.8	9.2	5.7	7.4	2.2	5.7	49.7
	3A	848	7.3	1.4	4.8	1.0	2.2	7.9	0.9	4.7	1.2	2.2	33.6
	3B	333	1.4	2.8	4.6	4.0	1.2	7.7	2.4	5.9	6.3	6.7	43.0
	4A	135	3.6	2.8	4.6	5.6	1.6	8.2	1.8	5.9	2.9	6.7	43.7
	4B	272	2.0	3.3	5.9	4.5	3.5	6.1	5.7	4.7	2.8	6.9	45.4
	24	194	3.4	1.9	4.0	6.3	3.2	5.6	6.9	5.7	2.3	2.6	41.9
	25	526	4.9	1.9	4.5	3.9	1.5	5.7	3.9	5.2	7.6	3.8	42.9
	26	485	6.3	2.8	4.9	2.6	0.9	6.6	4.0	5.3	1.9	3.8	39.1
Formulation 2	9	695	6.9	1.9	6.3	4.0	7.4	8.7	2.0	7.2	6.7	3.4	54.5
	10	826	5.3	3.9	4.6	2.3	4.3	8.2	8.9	6.0	2.8	2.4	48.7
	12	921	6.9	6.1	4.9	2.0	1.4	6.2	5.9	5.9	1.8	3.5	44.6
Formulation 3	5A	187	4.5	1.3	3.3	7.7	8.7	6.3	9.4	6.9	3.7	6.8	58.6
	5B	658	7.7	2.3	4.1	6.9	6.1	5.9	6.1	5.3	6.0	2.5	52.9
	6	317	4.6	1.8	5.4	6.9	5.5	6.7	5.3	6.9	4.5	6.9	54.5
	7	284	9.1	4.0	3.6	5.5	8.3	7.1	7.8	6.4	3.8	7.1	62.7
	11	388	8.5	1.6	5.8	5.0	8.0	8.2	6.7	5.7	5.8	5.7	61.0
Formulation 4	14	128	8.5	3.5	5.3	3.0	6.5	5.1	8.7	7.0	9.0	2.5	59.1
	16	163	7.9	2.3	3.4	6.4	3.2	6.9	5.6	6.3	0.4	4.4	46.8
	17	911	8.5	3.6	3.7	5.3	4.7	5.7	4.1	7.9	0.0	5.6	49.1
Formulation 5	8	629	2.9	1.4	3.8	3.3	8.4	7.3	7.4	5.5	6.8	4.7	51.5
	13	371	0.4	5.5	3.6	3.5	4.7	8.1	3.1	4.7	0.4	5.0	39.0
	19	164	8.5	2.9	3.3	7.2	8.1	7.4	7.8	6.9	1.3	5.6	59.0
	22	792	7.2	4.7	3.9	4.6	8.4	8.4	7.6	7.5	8.0	6.1	66.4
Formulation 6	15	972	2.4	3.9	4.5	4.6	6.1	7.0	3.6	5.5	10.0	3.1	50.7
	23	256	3.4	2.3	4.0	5.0	2.5	7.0	7.2	6.2	9.0	2.1	48.7
Formulation 7	18	427	6.7	2.3	4.5	5.5	6.8	4.1	8.6	6.8	3.5	5.5	54.3
	20	461	3.7	1.1	4.4	3.9	8.6	6.1	6.4	5.7	0.5	3.5	43.9
	21	191	6.6	1.0	4.4	2.6	5.2	4.7	2.5	6.7	4.3	4.7	42.7
Total			140.2	77.2	120.6	114.5	122	191.8	137.5	161.7	111.5	125.5	
Mean			5.19	2.86	4.47	4.24	4.52	7.1	5.09	5.99	4.13	4.65	

Appendix 5.6 (Cont.) Ratio on line scale acceptability test for snack base formulation

Formulation	Trial code	Product code	Ratio on line scale acceptability test of each panellist										Total
			11	12	13	14	15	16	17	18	19	20	
Formulation 1	1A	116	8.2	4.9	6.5	8.2	0.6	5.0	5.5	4.2	0.6	1.7	45.4
	1B	747	4.7	2.4	6.3	9.3	9.7	6.2	4.5	3.1	0.6	4.2	51.0
	2A	138	2.8	2.7	6.8	8.0	8.2	4.1	6.5	8.0	0.5	8.3	55.9
	2B	919	1.2	5.6	7.2	9.1	1.1	4.5	9.0	7.1	3.3	0.1	48.2
	3A	848	1.3	1.4	7.6	9.3	3.0	4.4	8.0	4.1	2.4	0.1	41.6
	3B	333	7.5	6.0	6.9	7.5	8.5	2.3	2.0	4.6	2.0	2.7	50.0
	4A	135	1.2	2.7	8.3	9.2	0.1	4.2	7.5	3.8	0.6	2.3	39.9
	4B	272	4.9	5.7	8.8	8.4	9.7	6.3	9.0	5.4	3.8	2.4	64.4
	24	194	5.0	3.8	6.5	8.8	6.5	3.1	6.5	6.2	0.5	8.8	55.7
	25	526	8.6	4.5	6.8	8.2	8.9	5.3	8.0	3.6	1.0	6.0	60.9
	26	485	2.8	4.3	8.1	7.7	0.9	5.2	7.0	3.6	1.8	0.3	41.7
Formulation 2	9	695	3.9	4.0	8.1	9.1	2.5	6.1	7.0	4.8	4.5	0.0	50.0
	10	826	5.8	2.9	8.0	8.6	0.3	6.0	9.0	4.4	9.3	0.2	54.5
	12	921	6.1	3.2	7.2	9.2	6.9	2.2	7.0	7.3	2.1	2.8	54.0
Formulation 3	5A	187	2.2	4.7	7.9	8.9	6.8	6.1	9.5	5.2	6.1	1.3	58.7
	5B	658	0.6	4.0	7.0	8.5	0.2	7.2	8.5	5.3	3.4	6.4	51.1
	6	317	1.4	3.5	7.5	7.3	9.3	5.3	8.5	5.5	6.1	5.5	59.9
	7	284	7.3	5.2	7.6	8.6	9.7	3.4	8.0	4.1	7.6	5.1	66.7
	11	388	4.4	6.4	7.3	8.9	7.7	5.8	7.0	4.7	4.7	0.1	57.0
Formulation 4	14	128	9.1	4.5	8.6	8.1	5.6	8.1	3.0	7.2	9.2	8.4	71.8
	16	163	4.1	5.8	8.6	8.9	2.1	6.1	8.5	5.0	4.0	6.7	59.8
	17	911	4.2	4.1	8.2	9.2	8.3	5.0	6.0	6.4	8.4	1.5	61.3
Formulation 5	8	629	6.5	3.0	8.8	8.3	10.0	4.2	7.5	6.0	5.7	1.1	61.1
	13	371	5.5	3.3	8.0	8.0	7.9	2.7	7.0	5.9	4.3	0.3	52.9
	19	164	2.3	4.0	7.7	8.7	5.0	6.8	7.0	3.1	7.3	1.6	53.5
	22	792	2.4	7.2	7.6	8.0	9.6	6.1	6.0	7.4	9.5	9.2	73.0
Formulation 6	15	972	5.0	3.6	8.3	8.0	0.1	3.6	7.5	6.1	5.8	1.1	49.1
	23	256	3.2	3.8	9.1	8.5	8.2	2.2	6.0	5.2	2.7	2.8	51.7
Formulation 7	18	427	6.7	4.2	9.4	8.4	1.1	6.4	8.0	6.2	4.7	4.7	59.8
	20	461	5.4	2.7	8.2	8.2	8.9	7.3	8.5	6.7	2.7	2.1	60.7
	21	191	8.6	2.2	9.2	7.9	2.9	6.1	8.0	3.7	6.3	3.8	58.7
Total			119	113.4	206.2	230	149.2	135.3	190.5	142.1	115.1	88.2	
Mean			4.41	4.2	7.64	8.52	5.53	5.01	7.06	5.26	4.26	3.27	

Appendix 5.6 (Cont.) Ratio on line scale acceptability test for snack base formulation

Formulation	Trial code	Product code	Ratio on line scale acceptability test on each panellist 21	22	23	24	25	26	27	28	29	30	Total	Total Sum	Mean
Formulation 1	1A	116	4.1	3.7	2.2	2.4	2.8	5.3	9.4	7.8	0.9	4.3	42.9	127.6	4.25 ± 2.56
	1B	747	4.7	3.4	3.4	1.0	2.0	2.4	3.3	8.2	0.3	1.9	30.6	117.2	3.91 ± 2.57
	2A	138	6.1	1.0	3.9	1.0	3.9	2.4	0.7	5.8	0.0	4.7	19.5	114.6	3.82 ± 2.53
	2B	919	3.5	5.4	3.4	3.2	8.0	7.5	1.3	9.0	8.6	2.5	52.4	150.3	5.01 ± 2.75
	3A	848	1.5	3.2	0.4	0.7	4.0	8.0	0.4	7.3	0.6	3.9	30.0	105.2	3.51 ± 2.83
	3B	333	0.5	4.4	1.2	1.2	2.9	2.0	1.1	7.3	2.2	7.2	30.0	123.0	4.10 ± 2.52
	4A	135	7.1	1.6	0.6	2.4	4.2	3.9	0.2	5.4	8.9	6.9	41.2	124.8	4.16 ± 2.75
	4B	272	3.2	2.4	1.8	3.2	7.5	1.2	7.3	10.0	3.0	5.5	45.1	154.9	5.16 ± 2.48
	24	194	4.7	4.3	2.6	4.5	1.4	5.0	2.0	5.8	2.9	4.9	38.1	135.7	4.52 ± 2.07
	25	526	5.2	4.7	3.1	1.9	7.7	4.9	7.3	7.6	1.3	4.7	48.4	152.2	5.07 ± 2.27
	26	485	3.9	3.2	2.3	1.5	3.1	1.2	2.1	6.2	0.0	8.3	31.8	112.6	3.75 ± 2.37
Formulation 2	9	695	6.2	6.1	4.0	4.6	6.5	6.5	7.9	7.6	4.3	4.9	58.6	163.1	5.44 ± 2.18
	10	826	5.0	9.3	5.6	4.1	7.3	6.4	8.8	8.5	7.4	5.3	67.7	170.9	5.70 ± 2.63
	12	921	3.9	5.3	5.7	5.1	5.4	8.6	7.4	9.4	9.1	5.8	65.7	164.3	5.48 ± 2.30
Formulation 3	5A	187	4.1	3.2	0.2	4.5	7.3	9.8	9.2	5.4	1.1	7.3	52.1	169.4	5.65 ± 2.75
	5B	658	4.5	4.7	1.3	5.8	6.5	6.4	7.1	8.1	3.5	3.2	51.1	155.1	5.17 ± 2.26
	6	317	6.8	6.1	5.8	1.3	3.7	5.5	6.2	6.4	2.4	8.5	52.7	167.1	5.57 ± 2.01
	7	284	5.5	5.0	4.4	5.8	6.9	4.2	0.6	6.5	2.8	2.4	44.1	173.4	5.78 ± 2.18
	11	388	6.9	10	5.7	4.4	8.0	7.4	6.3	9.2	2.6	5.7	66.2	184.2	6.14 ± 2.18
Formulation 4	14	128	4.1	9.6	2.2	3.2	7.7	6.8	1.9	8.3	1.2	3.9	48.9	179.8	5.99 ± 2.62
	16	163	6.2	5.1	7.1	5.7	5.1	9.4	0.2	6.9	7.7	6.2	59.6	166.2	5.54 ± 2.34
	17	911	5.0	7.8	2.9	6.6	6.0	6.7	1.1	9.8	1.9	8.6	56.4	166.8	5.56 ± 2.55
Formulation 5	8	629	6.0	4.2	7.0	3.7	8.9	5.4	2.4	9.4	3.6	6.2	56.8	169.4	5.65 ± 2.40
	13	371	2.6	5.7	1.2	4.1	2.6	6.8	0.5	7.5	0.3	8.6	39.9	131.8	4.39 ± 2.65
	19	164	7.7	3.3	4.8	1.9	8.9	8.6	1.3	8.3	5.0	4.5	54.3	166.8	5.56 ± 2.53
	22	792	3.7	4.1	4.4	5.6	7.5	8.8	8.9	8.4	8.0	8.1	67.5	206.9	6.90 ± 1.93
Formulation 6	15	972	2.4	8.4	7.3	3.3	8.2	9.2	8.2	6.6	8.0	7.2	68.8	168.6	5.62 ± 2.53
	23	256	7.1	1.0	2.8	1.9	7.4	3.0	2.1	9.4	0.4	2.9	38.0	138.4	4.61 ± 2.68
Formulation 7	18	427	7.0	8.2	4.7	2.9	6.2	7.8	8.7	10.0	5.3	6.6	67.4	181.5	6.05 ± 2.13
	20	461	5.3	5.8	5.3	6.2	8.4	5.7	0.7	9.3	3.8	2.0	52.5	157.1	5.24 ± 2.58
	21	191	6.2	2.5	6.1	5.2	6.2	6.1	1.6	7.1	3.1	6.0	50.1	151.5	5.05 ± 2.14
Total			125.1	135.2	94.5	92.7	154.0	160.3	113.1	206.7	97.6	151.2			
Mean			4.63	5.01	3.50	3.43	5.70	5.94	4.19	7.66	3.61	5.6			

Appendix 5.7 Extrudate functional and physical properties analysis

Ingredients	Trial Code	MC (%wb)	WAI	WSI (%)	NSI (%)	SME (W Hr/kg)	Tg (°C)	BS (N)	Colour				Acceptability
									L^*	a^*	b^*	ΔE^*	
Formulation 1	1A	6.81	5.11	24.7	16.6	168	46.6	4.87 ± 1.41	73.5	2.29	28.7	35.6	4.25 ± 2.56
	1B	7.02	6.08	30.0	16.8	166	46.5	5.19 ± 1.13	73.2	3.24	31.2	37.8	3.91 ± 2.57
	2A	6.18	5.23	25.4	23.4	171	40.1	3.86 ± 0.58	72.2	4.05	28.4	36.4	3.82 ± 2.53
	2B	6.41	5.65	29.6	27.2	169	39.8	3.34 ± 0.16	72.8	3.51	28.5	36.0	5.01 ± 2.75
	3A	7.03	4.94	12.9	25.4	173	38.2	4.10 ± 0.73	70.4	3.72	29.1	38.2	3.51 ± 2.83
	3B	6.62	5.41	23.7	22.7	182	38.3	3.84 ± 1.75	72.1	3.86	29.4	37.2	4.10 ± 2.52
	4A	5.81	5.81	28.6	25.2	165	34.3	4.88 ± 1.19	70.8	3.30	27.3	36.6	4.16 ± 2.75
	4B	6.23	5.27	22.4	23.7	167	33.7	3.79 ± 1.28	71.6	3.83	28.6	37.0	5.16 ± 2.48
	24	6.07	4.69	19.0	24.1	156	50.4	3.64 ± 0.54	71.6	4.19	27.2	36.1	4.52 ± 2.07
	25	6.15	5.60	22.9	21.3	177	47.2	3.68 ± 0.61	72.7	3.59	28.6	36.2	5.07 ± 2.27
	26	6.81	5.89	25.8	20.5	176	46.7	4.35 ± 0.76	71.4	3.95	29.8	38.0	3.75 ± 2.37
Formulation 2	9	5.95	5.14	25.5	19.1	182	40.3	4.06 ± 0.15	71.0	3.46	27.2	36.5	5.44 ± 2.18
	10	6.16	5.17	27.9	19.6	185	37.5	3.40 ± 1.26	69.7	5.03	27.8	38.0	5.70 ± 2.63
	12	6.97	4.73	22.1	21.9	171	41.8	4.25 ± 0.65	71.5	4.28	29.8	38.0	5.48 ± 2.30
Formulation 3	5A	6.45	4.50	28.9	18.3	151	38.9	3.26 ± 0.32	67.1	5.83	27.1	39.6	5.65 ± 2.75
	5B	5.69	4.50	24.7	18.4	177	40.7	3.15 ± 0.90	68.9	5.79	26.8	38.0	5.17 ± 2.26
	6	6.27	4.31	42.0	20.7	174	42.4	3.26 ± 0.35	66.8	6.17	27.0	39.8	5.57 ± 2.01
	7	6.39	4.53	41.4	18.0	194	37.4	3.37 ± 1.04	68.2	5.00	27.9	39.1	5.78 ± 2.18
	11	6.22	4.15	22.3	18.2	164	43.9	3.44 ± 0.95	68.8	5.56	28.1	38.9	6.14 ± 2.18
Formulation 4	14	6.63	4.11	15.8	17.2	206	41.3	3.19 ± 0.21	68.6	5.18	28.9	39.6	5.99 ± 2.62
	16	5.93	4.66	31.1	19.5	170	46.8	3.62 ± 0.17	67.3	5.64	26.7	39.2	5.54 ± 2.34
	17	6.89	4.47	25.1	19.6	194	56.7	3.39 ± 0.28	68.6	5.49	27.9	38.9	5.56 ± 2.55

Appendix 5.7 (Cont.) Extrudate functional and physical properties analysis

Ingredients	Trial Code	MC (%wb)	WAI	WSI (%)	NSI (%)	SME (W Hr/kg)	Tg (°C)	BS (N)	Colour L^*	a^*	b^*	ΔE^*	Acceptability
Formulation 5	8	6.90	4.42	31.2	22.0	188	37.9	4.15 ± 0.68	70.0	4.88	27.6	37.5	5.65 ± 2.40
	13	10.22	5.18	15.3	14.5	126	42.4	5.47 ± 1.17	72.7	2.82	31.9	38.6	4.39 ± 2.65
	19	6.32	4.61	32.0	18.8	169	41.1	3.30 ± 0.24	66.9	6.06	26.6	39.5	5.56 ± 2.53
	22	7.27	4.03	26.3	17.6	189	36.0	4.05 ± 1.33	67.4	5.84	28.6	40.3	6.90 ± 1.93
Formulation 6	15	7.17	4.79	20.8	21.6	187	39.6	3.41 ± 0.70	69.8	4.96	29.5	39.1	5.62 ± 2.53
	23	6.91	5.04	39.2	25.1	175	53.2	4.12 ± 0.38	70.4	4.93	28.2	37.7	4.61 ± 2.68
Formulation 7	18	6.73	4.60	17.9	18.3	176	45.7	3.58 ± 0.26	73.3	4.56	28.0	35.6	6.05 ± 2.13
	20	6.61	4.48	19.0	19.7	175	62.4	3.73 ± 0.67	71.1	4.63	27.2	36.5	5.24 ± 2.58
	21	6.82	4.46	21.4	17.4	191	42.9	3.27 ± 0.32	69.8	4.81	28.3	38.2	5.05 ± 2.14

Appendix 5.8 Coefficients of estimated quadratic models for the following parameters: moisture content (MC), water absorption index (WAI), water solubility index (WSI) and nitrogen solubility index (NSI)

Variable	Coefficient*	Parameters				
		MC (%)	WAI	WSI (%)	NSI (%)	SME
Constant	β0	7.170	4.463	21.492	19.443	200.331
Rice	β1	0.608 **	0.750 **	- 3.663	3.615 **	-10.361
Soya	β2	- 0.081	-1.009 **	6.868	- 4.012 **	1.406
Tapioca	β3	- 0.968 *	0.271	- 4.415	- 0.085	16.454
Screw speed	β4	- 0.026 ***	-0.006	0.059	0.067 *	0.316*
Water	β5	14.257 ***	1.205	- 80.883	0.027	-32.638
T4	β6	- 0.009	0.020	0.060	- 0.012	-1.229***
Rice * Soya	β12	- 0.427	-0.881	- 33.854 *	- 14.187 *	42.143
Rice * Tapioca	β13	4.467 **	0.792	- 42.350	- 2.447	0.547
Rice * Screw speed	β14	0.014	0.006	0.111	0.033	-0.213
Rice * Water	β15	- 8.608	-1.864	-198.957	29.559	164.805
Rice * T4	β16	- 0.041 *	0.004	- 0.149	- 0.042	0.918*
Soya * Tapioca	β23	- 3.771 *	-0.047	19.210	7.610	84.555*
Soya * Screw speed	β24	- 0.049 ***	0.001	0.093	- 0.045	0.804**
Soya * Water	β25	28.758 ***	4.030	- 97.263	-103.756 *	-244.554
Soya * T4	β26	0.063 ***	0.017	0.150	- 0.144	-1.404**
Tapioca * Screw speed	β34	0.095 **	-0.014	- 0.610	0.023	-1.607*
Tapioca * Water	β35	-52.372 **	-5.314	879.281**	193.562 *	163.336
Tapioca * T4	β36	- 0.051	-0.060	0.036	0.540 *	1.131
Screw speed * Water	β45	- 0.551 **	-0.131	- 3.967	- 1.391	13.803*
Screw speed * T4	β46	- 0.002 ***	0.000	0.025**	0.002	0.020
Water * T4	β56	1.470 ***	0.111	3.495	- 0.831	-8.189
Rice * Rice	β11	- 2.093 *	0.345	53.554**	13.971*	-37.779
Soya * Soya	β22	2.828 **	1.021	26.109	11.216	-100.039**
Tapioca * Tapioca	β33	- 2.011	-1.355	45.635	- 7.803	-136.790
Screw speed * Screw speed	β44	- 0.001	0.002	0.001	- 0.006	0.047
Water * Water	β55	46.286	23.567	-9592.73	-590.536	1039.720
T4 * T4	β66	- 0.004	-0.002	- 0.063	- 0.016	0.038
r^2		0.958***	0.851*	0.837 (P=0.06)	0.906**	0.911**
Fit of model		0.8687	0.9012	1.0487	1.0456	1.007

* Response Y = β0 + β1 (rice) + β2 (soya) + β3 (tapioca) + β4 (screw speed) + β5 (water) + β6 (T4) + β12 (rice * soya) + β13 (rice * tapioca) + β14 (rice * screw speed) + β15 (rice * water) + β16 (rice * T4) + β23 (soya * tapioca) + β24 (soya * screw speed) + β25 (soya * water) + β26 (soya * T4) + β34 (tapioca * screw speed) + β35 (tapioca * water) + β36 (tapioca * T4) + β45 (screw speed* water) + β46 (screw speed* T4) + β56 (water * T4) + β11 ($rice^2$) + β22 ($soya^2$) + β33 ($tapioca^2$) + β44 ($screw\ speed^2$) + β55 ($water^2$) + β66 ($T4^2$)
where Y = MC or WAI or WSI or NSI or SME

* – $0.05 < P \leq 0.1$
** – $0.01 < P \leq 0.05$
*** – $P \leq 0.01$

Appendix 5.9 Coefficients of estimated quadratic models for the following parameters: breaking strength (BS), L^* colour, a^* colour, b^* colour, ΔE^* colour and acceptability (accept.)

Variable	Coeffi-cient*	Parameters					
		BS	L^*	a^*	b^*	ΔL^*	Accept.
Constant	β0	3.189	70.507	5.478	27.889	37.516	5.429
Rice	β1	1.039 **	2.425 *	-1.442 **	1.345 *	-1.038	- 0.925 *
Soya	β2	- 0.406	-2.981 **	1.661 **	-1.320 *	1.479	1.669 **
Tapioca	β3	- 1.224	0.408	-0.063	-0.309	-0.500	- 1.011
Screw speed	β4	- 0.017	-0.045	0.028 *	-0.038 **	0.008	0.008
Water	β5	2.801	14.526	-3.933	27.129 **	7.749	- 6.708
T4	β6	- 0.008	-0.001	-0.012	-0.044 *	-0.028	- 0.013
Rice * Soya	β12	- 0.152	6.999	-1.558	-2.042	-6.641	1.729
Rice * Tapioca	β13	0.432	-0.120	-1.273	5.735	4.044	- 2.405
Rice * Screw speed	β14	- 0.008	-0.031	0.014	-0.007	0.018	- 0.003
Rice * Water	β15	- 9.641	10.381	12.243	-3.861	-8.786	- 1.013
Rice * T4	β16	- 0.020	0.014	-0.018	-0.040	-0.047	0.027
Soya * Tapioca	β23	- 4.624	-7.607	3.912	-1.886	4.311	2.852
Soya * Screw speed	β24	- 0.011	0.019	0.001	-0.035	-0.037	0.004
Soya * Water	β25	21.488	27.165	-23.525	45.99 **	10.120	- 3.611
Soya * T4	β26	0.037	0.030	-0.035	0.060	0.027	- 0.068 *
Tapioca * Screw speed	β34	0.056	0.043	-0.048	0.120	0.049	- 0.004
Tapioca * Water	β35	-29.253	-106.5	26.827	-114.272 *	-0.707	13.022
Tapioca * T4	β36	- 0.040	-0.128	0.155	-0.047	0.069	0.107
Screw speed * Water	β45	- 0.250	-1.093	0.506	-0.509	0.457	0.147
Screw speed * T4	β46	- 0.000	-0.003	0.001	-0.003 *	0.001	0.001
Water * T4	β56	0.330	0.489	0.186	1.403	0.665	0.130
Rice * Rice	β11	- 0.104	-6.157	2.091	-1.359	3.666	- 0.206
Soya * Soya	β22	3.050	-3.134	-0.683	3.471	4.783	- 3.720
Tapioca * Tapioca	β33	6.645	12.435	-3.983	-7.329	-14.228	- 0.238
Screw speed * Screw speed	β44	- 0.001	-0.001	-0.001	0.003	0.002	0.002
Water * Water	β55	391.746	1924.2	-885.61	443.191	-1206.17	-159.070
T4 * T4	β66	- 0.002	-0.004	-0.003	-0.004	-0.001	0.002
r^2		0.767 (P=0.2)	0.872*	0.884*	0.888*	0.774 (P=0.19)	0.801 (P=0.12)
Fit of model		1.2519	1.4690	1.5551	0.7969	1.1833	1.1276

* Response Y = β0 + β1 (rice) + β2 (soya) + β3 (tapioca) + β4 (screw speed) + β5 (water) + β6 (T4) + β12 (rice * soya) + β13 (rice * tapioca) + β14 (rice * screw speed) + β15 (rice * water) + β16 (rice * T4) + β23 (soya * tapioca) + β24 (soya * screw speed) + β25 (soya * water) + β26 (soya * T4) + β34 (tapioca * screw speed) + β35 (tapioca * water) + β36 (tapioca * T4) + β45 (screw speed * water) + β46 (screw speed * T4) + β56 (water * T4) + β11 ($rice^2$) + β22 ($soya^2$) + β33 ($tapioca^2$) + β44 ($screw\ speed^2$) + β55 ($water^2$) + β66 ($T4^2$)
where Y = BS or L^* or a^* or b^* or or Accept.

* – $0.05 < P \leq 0.1$
** – $0.01 < P \leq 0.05$
*** – $P \leq 0.01$

Appendix 6.1 Analysis of variance (ANOVA) and Tukey's honestly significant different test used for the snack basic formulation acceptability

Source of Variation	SS	df	MS	F	P-value	F-crit (5%)
Panellists	1789.43	29	61.70	15.06*	0.0001	1.5685
Samples	597.31	30	19.91	4.86*	0.0001	
Error	3564.26	870	4.10			
Total	5951.00	929				

Tukey's honestly significant different test test

Trial code[1)]	Total	Mean[2)3)]
22	206.9	6.90[a]
11	184.2	6.14[ab]
18	181.5	6.05[abc]
14	179.8	5.99[abc]
7	173.4	5.78[abcd]
10	170.9	5.70[abcde]
5A	169.4	5.65[abcde]
8	169.4	5.65[abcde]
15	168.6	5.62[abcde]
6	167.1	5.57[abcde]
17	166.8	5.56[abcde]
19	166.8	5.56[abcde]
16	166.2	5.54[abcde]
12	164.3	5.48[abcdef]
9	163.1	5.44[abcdef]
20	157.1	5.24[abcdef]
5B	155.1	5.17[abcdef]
4B	154.9	5.16[abcdef]
25	152.2	5.07[abcdef]
21	151.5	5.05[abcdef]
2B	150.3	5.01[abcdef]
23	138.4	4.61[bcdef]
24	135.7	4.52[bcdef]
13	131.8	4.39[bcdef]
1A	127.6	4.25[bcdef]
4A	124.8	4.16[cdef]
3B	123.0	4.10[cdef]
1B	117.2	3.91[def]
2A	114.6	3.82[def]
26	112.6	3.75[ef]
3A	105.2	3.51[f]

1) Trial codes refer to Appendix 5.1
2) A lower mean indicates a lower acceptability
3) Different letter at the same column indicates significantly difference on treatments (P<0.05)

Appendix 6.2 Cost of snack extrudate for each formulation

Ingredients	Trial code[a]	Formulation proportion (%)					Cost (Rp./kg)
		Rice	Soya	Tapioca	Corn	Bak. Soda	
Formula 1	1A	20	10	10	59.6	0.4	1480.64
	1B	20	10	10	59.6	0.4	1480.64
	2A	20	10	10	59.6	0.4	1480.64
	2B	20	10	10	59.6	0.4	1480.64
	3A	20	10	10	59.6	0.4	1480.64
	3B	20	10	10	59.6	0.4	1480.64
	4A	20	10	10	59.6	0.4	1480.64
	4B	20	10	10	59.6	0.4	1480.64
	24	20	10	10	59.6	0.4	1480.64
	25	20	10	10	59.6	0.4	1480.64
	26	20	10	10	59.6	0.4	1480.64
Formula 2	9	20	20	0	59.6	0.4	1732.64
	10	20	20	0	59.6	0.4	1732.64
	12	20	20	0	59.6	0.4	1732.64
Formula 3	5A	2	28	10	59.6	0.4	1909.04
	5B	2	28	10	59.6	0.4	1909.04
	6	2	28	10	59.6	0.4	1909.04
	7	2	28	10	59.6	0.4	1909.04
	11	2	28	10	59.6	0.4	1909.04
Formula 4	14	7	28	5	59.6	0.4	1916.04
	16	7	28	5	59.6	0.4	1916.04
	17	7	28	5	59.6	0.4	1916.04
Formula 5	8	12	28	0	59.6	0.4	1923.04
	13	12	28	0	59.6	0.4	1923.04
	19	12	28	0	59.6	0.4	1923.04
	22	12	28	0	59.6	0.4	1923.04
Formula 6	15	20	15	5	59.6	0.4	1606.64
	23	20	15	5	59.6	0.4	1606.64
Formula 7	18	11	19	10	59.6	0.4	1694.84
	20	11	19	10	59.6	0.4	1694.84
	21	11	19	10	59.6	0.4	1694.84

[a] Code A & B indicates replicates

Appendix 6.3 Ranking test questionnaire used in the second stage of flavour screening

PRODUCT TESTING

Date : ....
Name : ....

You will be provided with 5 sets of samples (i.e. cheesy flavour; chicken flavour; barbecue flavour; spicy flavour and savory flavour). Each set will be served separately.
Please rank the samples on each set by writing the code (1 = the most preferred product).

<u>CHEESY FLAVOUR</u> : 1 = ...
2 = ...
3 = ...

<u>CHICKEN FLAVOUR</u> : 1 = ...
2 = ...
3 = ...
4 = ...

<u>BARBECUE FLAVOUR</u> : 1 = ...
2 = ...
3 = ...

<u>SPICY FLAVOUR</u> : 1 = ...
2 = ...
3 = ...

<u>MEXICAN FLAVOUR</u> : 1 = ...
2 = ...

Comments:

____

____

____

Thank you for your cooperation

Appendix 6.4 Questionnaire for the preference product test used in the flavour development

PRODUCT TESTING

Date : ....
Name : ....

Please give a score to each sample on the blank that best reflects your preference to the expanded extrusion snack.
Scores : 1 = Like very much
2 = Like moderately
3 = Like slightly
4 = Neither like nor dislike
5 = Dislike slightly
6 = Dislike moderately
7 = Dislike very much

Please ensure you rinse your mouth with plain water, before testing each sample.

Sample codes	Colour	Overall appearance	Aroma	Flavour	Overall preference
.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....

Please give comments on how the products' colour, overall appearance, aroma and flavour affect your overall preference:

Thank you for your cooperation

Appendix 6.5 Questionnaire for the ranking test used in the flavour development

PRODUCT TESTING

Date : ....
Name : ....

Please rank the following samples that best reflects your preference to the expanded extrusion snack.
(1 = the most preferred sample; 4 = the least preferred sample)

Please ensure you rinse your mouth with plain water, before testing each sample.

Product: (rank order)

A. Corn flavour ......
B. Spicy flavour ......
C. Barbecue flavour ......
D. Savoury flavour ......

Comments :

____
____
____
____
____

Thank you for your cooperation

Appendix 6.6 Calculation of product cost

Flavours	Flavour powder		Snack base		Vegetable oil (Coating agent)		Other ingredients[a)]		Total snack cost	Further screening (+/-)[b)]
	Amount (g)	Price (Rp./kg)	Amount (g)	Price (Rp./kg)	Amount (g)	Price (Rp./kg)	Amount (g)	Price (Rp./kg)	(Rp./kg)	
1. Cheese powder - ATCP 1013	15	7800.00	60	1923.04	30	2000.00	WPC = 5 Salt = 1 Tart = 0.02	12100.00 1144.70 69419.00	3201.36	--
2. Cheese powder - ATCP 1014	15	11242.00	60	1923.04	30	2000.00	-	-	3276.31	--
3. Cheese powder - ASP 2001	20	6457.00	60	1923.04	30	2000.00	-	-	2768.39	--
4. Cheese powder - A 2003 SS	20	6413.00	60	1923.04	30	2000.00	-	-	2760.39	+
5. Cheese powder - AFP 355	15	9240.00	60	1923.04	30	2000.00	-	-	2990.31	--
6. Cheese powder - AFP 355 Cheese powder - ASP 2001	5 10	9240.00 6457.00	60	1923.04	30	2000.00	Tart. = 0.2	69419.00	2852.06	+
7. Cheese powder - ATCP 1014 Cheese powder - ATCP 1013	10 5	11242.00 7800.00	60	1923.04	30	2000.00	WPC = 5 Salt = 1 Tart. = 0.02	12100.00 1144.70 69419.00	3511.40	--

a) WPC = Whey protein concentrate powder
Tart. = tartrazine (colouring agent)
SY = sunset yellow (colouring agent)

b) (+/-) ; + = carried on for further screening
-- = screened out

Appendix 6.6 (Cont.) Calculation of product cost

Flavours	Flavour powder		Snack base		Vegetable oil (Coating agent)		Other ingredients[a)]		Total snack cost	Further screening (+/-)[b)]
	Amount (g)	Price (Rp./kg)	Amount (g)	Price (Rp./kg)	Amount (g)	Price (Rp./kg)	Amount (g)	Price (Rp./kg)	(Rp./kg)	
8. Sour cream & chives - 9110	10	12554.50	60	1923.04	30	2000.00	WPC = 10 Tart = 0.1	12100.00 69419.00	3895.27	+
9. Chicken flavour base - 7718	5	21415.50	60	1923.04	30	2000.00	WPC = 4	12100.00	3342.02	+
10. Crispy fried chicken - APO 2656	8.5	14750.50	60	1923.04	30	2000.00	Tart. = 0.14	69419.00	3653.84	+
11. Chicken saroline - E 4.6264	6	8492.75	60	1923.04	30	2000.00	WPC = 2 Sugar= 0.55	12100.00 1500.00	2550.62	+
12. Mexican chicken 2 - E 5.6064	6	13588.40	60	1923.04	30	2000.00	-	-	2676.18	+
13. Barbecue seasoning - 9127	7	11077.50	60	1923.04	30	2000.00	-	-	2607.47	+
14. Hot 'n spicy barbecue - E 5.6065	7	12332.95	60	1923.04	30	2000.00	-	-	2698.07	+
15. Barbecue saroline - E 5.6000	6	9157.40	60	1923.04	30	2000.00	-	-	2399.24	+
16. Barbecue chip saroline - E 4.6150	6	9157.40	60	1923.04	30	2000.00	-	-	2399.24	--

[a)] WPC = Whey protein concentrate powder
Tart. = tartrazine (colouring agent)
SY = sunset yellow (colouring agent)

[b)] (+/-) ; + = carried on for further screening
-- = screened out

Appendix 6.6 (Cont.) Calculation of product cost

Flavours	Flavour powder		Snack base		Vegetable oil (Coating agent)		Other ingredients[a]		Total snack cost	Further screening (+/-)[b]
	Amount (g)	Price (Rp./kg)	Amount (g)	Price (Rp./kg)	Amount (g)	Price (Rp./kg)	Amount (g)	Price (Rp./kg)	(Rp./kg)	
17. Cajun - 5492	17	10339.00	60	1923.04	30	2000.00	-	-	3281.73	+
18. Curry - 7314	15	12554.50	60	1923.04	30	2000.00	-	-	3463.81	+
19. Ethnican - QZ 02346	7	12554.50	60	1923.04	30	2000.00	Salt = 1 Sugar = 2	1144.70 1500.00	3233.35	+
20. Nacho - 9166	15	14750.50	60	1923.04	30	2000.00	-	-	3777.52	+
21. Spicy jalapeno seasoning - 9161	10	12554.50	60	1923.04	30	2000.00	-	-	3009.27	+
22. Roasted Corn - QZ 02352	7	25847.50	60	1923.04	30	2000.00	Sugar = 7 SY= 0.03 Tart.= 0.06	1500.00 72373.00 69419.00	3584.89	+

[a] WPC = Whey protein concentrate powder
Tart. = tartrazine (colouring agent)
SY = sunset yellow (colouring agent)

[b] (+/-) ; + = carried on for further screening
-- = screened out

Appendix 6.7 Results of preference ranking test on each flavour group

Cheesy flavour

Types of flavour	Participants on each rank			$\sum_{i=3}^{1}$ (x.n)[a]
	I	II	III	
1. Cheese powder - AFP 355 & ASP 2001	6	1	1	21[1]
2. Cheese powder - A 2003 SS	1	6	1	16
3. Sour cream & chives - 9110	1	1	6	11

Chicken flavour

Types of flavour	Participants on each rank				$\sum_{i=4}^{1}$ (x.n)[a]
	I	II	III	IV	
1. Chicken saroline - E 4.6264	2	4	1	1	23[2]
2. Mexican chicken 2 - E 5.6064	3	1	3	1	22[2]
3. Chicken flavour base - 7718	1	2	3	2	18
4. Crispy fried chicken - APO 2656	2	1	1	4	17

Barbecue flavour

Types of flavour	Participants on each rank			$\sum_{i=3}^{1}$ (x.n)[a]
	I	II	III	
1. Barbecue saroline - E 5.6000	2	6	-	18[2]
2. Barbecue seasoning - 9127	4	1	3	17[2]
3. Hot 'n spicy barbecue - E 5.6065	2	1	5	13

Spicy flavour

Types of flavour	Participants on each rank			$\sum_{i=3}^{1}$ (x.n)[a]
	I	II	III	
1. Cajun - 5492	6	1	1	21[1]
2. Curry - 7314	2	4	2	16
3. Ethnican - QZ 02346	-	3	5	11

Savoury/mexican flavour

Types of flavour	Participants on each rank		$\sum_{i=2}^{1}$ (x.n)[a]
	I	II	
1. Nacho - 9166	6	2	14[1]
2. Spicy jalapeno seasoning - 9161	2	6	10

[a] x = number of participants on each rank; n = factor for the degree of preference, higher n value for the higher preference

[1] selected flavour on each group

[2] tested again

Appendix 6.8 Re-evaluation test for the chicken and barbecue flavours

Chicken flavour

Types of flavour	Participants on each rank				$\sum_{i=4}^{1}$ (x.n)[a]
	I	II	III	IV	
1. Mexican chicken 2 - E 5.6064	4	7	2	1	31
2. Chicken saroline - E 4.6264	4	2	6	2	31
3. Chicken flavour base - 7718	2	3	5	4	36
4. Crispy fried chicken - APO 2656	4	2	1	7	44[1)]

Barbecue flavour

Types of flavour	Participants on each rank			$\sum_{i=3}^{1}$ (x.n)[a]
	I	II	III	
1. Barbecue saroline - E 5.6000	7	7	-	35[1)]
2. Barbecue seasoning - 9127	4	5	5	27
3. Hot 'n spicy barbecue - E 5.6065	3	2	9	22

[a)] x = number of participants on each rank; n = factor for the degree of preference, higher n value for the higher preference (n=1 lowest preference)

[1)] selected flavour on each group

Appendix 6.9 Panellists' responds for each sample[1)]

Product : *Cheese flavoured snack*

Panellists	Overall Preference	Overall Appearance	Flavour	Aroma	Colour
1	3	3	3	4	3
2	6	7	3	5	7
3	2	1	1	3	1
4	4	5	4	2	7
5	3	5	3	2	7
6	1	1	2	1	2
7	1	4	2	5	1
8	3	7	2	4	2
9	3	3	3	3	3
10	1	6	1	2	3
11	6	5	6	6	6
12	2	5	2	4	5
13	3	6	3	3	3
14	5	7	6	2	6
15	3	7	2	1	7
16	2	6	1	2	6
17	4	6	4	5	2
18	6	2	6	6	6
19	2	5	1	6	6
20	6	7	3	1	6
21	7	6	4	5	7
22	6	4	2	5	7
23	6	5	6	6	6
24	3	6	1	2	5
25	6	3	5	6	6
26	3	3	2	3	1
27	6	3	4	7	7
28	5	2	4	4	5
Total	107	130	86	105	133
Means	3.8214	4.6429	3.0714	3.7500	4.7500

Product : *Chicken flavoured snack*

Panellists	Overall Preference	Overall Appearance	Flavour	Aroma	Colour
1	3	3	3	3	3
2	3	6	2	4	4
3	3	3	2	1	4
4	3	3	3	3	3
5	6	5	6	7	6
6	3	3	4	3	2
7	3	4	5	3	5
8	3	2	4	3	3
9	5	4	5	5	4
10	4	4	4	3	4
11	5	2	4	2	5
12	3	4	2	2	4
13	3	4	3	6	3
14	5	2	6	2	6
15	4	4	2	2	2
16	4	2	1	3	2
17	4	5	3	4	4
18	5	4	5	5	4
19	2	1	2	2	5
20	5	2	7	3	5
21	3	6	3	3	3
22	3	3	3	2	3
23	4	2	5	4	5
24	2	6	2	2	2
25	4	3	4	5	5
26	3	4	4	3	3
27	3	3	2	3	4
28	6	2	4	4	4
Total	104	96	100	92	107
Means	3.7143	3.4286	3.5714	3.2857	3.8214

1) 7 points hedonic scale, where: 1 = Like very much; 2 = Like moderately; 3 = Like slightly; 4 = Neither like nor dislike; 5 = Dislike slightly; 6 = Dislike moderately; 7 = Dislike very much

Appendix 6.9 (cont.) Panellists' responds for each sample[1)]

Product : *Barbecue flavoured snack*

Panellists	Overall Preference	Overall Appearance	Flavour	Aroma	Colour
1	4	4	3	3	4
2	4	2	4	5	3
3	2	3	1	1	3
4	3	2	4	2	2
5	5	5	6	2	3
6	2	2	2	2	2
7	3	4	3	4	5
8	3	2	3	3	3
9	2	3	2	2	3
10	5	2	5	4	4
11	4	2	3	5	3
12	3	3	4	3	4
13	4	2	3	4	4
14	2	2	4	3	2
15	2	3	2	1	1
16	1	2	5	5	1
17	3	4	2	3	3
18	4	4	4	4	3
19	2	1	2	3	2
20	3	1	6	5	1
21	2	3	2	2	2
22	1	3	2	2	1
23	3	3	2	3	2
24	2	2	2	1	1
25	4	5	1	2	3
26	3	3	2	3	4
27	2	4	2	4	2
28	3	2	3	3	2
Total	78	78	84	85	73
Means	2.7857	2.7857	3.0000	3.0357	2.6071

Product : *Spicy flavoured snack*

Panellists	Overall Preference	Overall Appearance	Flavour	Aroma	Colour
1	4	4	3	3	4
2	4	2	4	5	4
3	1	4	2	1	3
4	2	3	2	2	2
5	2	3	1	2	2
6	2	3	2	2	2
7	3	4	2	3	3
8	3	2	3	4	3
9	3	4	3	3	4
10	3	1	3	4	4
11	2	3	2	4	2
12	4	3	3	3	3
13	2	2	2	2	2
14	1	2	1	3	3
15	3	2	2	3	3
16	2	2	1	2	2
17	3	3	2	3	3
18	3	4	3	2	2
19	2	1	1	4	2
20	3	2	3	4	3
21	2	3	2	3	2
22	1	3	1	5	3
23	3	3	3	4	3
24	2	2	2	2	2
25	1	5	1	2	1
26	4	3	2	4	5
27	1	4	2	3	1
28	4	2	2	2	3
Total	70	79	60	84	76
Means	2.5000	2.8214	2.1429	3.0000	2.7143

1) 7 points hedonic scale, where: 1 = Like very much; 2 = Like moderately; 3 = Like slightly; 4 = Neither like nor dislike; 5 = Dislike slightly; 6 = Dislike moderately; 7 = Dislike very much

Appendix 6.9 (cont.) Panellists' responds for each sample[1)]

Product : *Savoury flavoured snack*

Panellists	Overall Preference	Overall Appearance	Flavour	Aroma	Colour
1	4	4	4	3	4
2	3	7	1	3	2
3	1	1	1	1	1
4	2	5	1	2	2
5	7	3	6	7	1
6	3	2	3	3	1
7	1	3	1	1	2
8	3	3	2	4	3
9	3	5	2	3	2
10	2	3	2	3	4
11	3	3	3	3	2
12	5	3	5	2	2
13	3	5	2	5	3
14	3	5	5	3	3
15	1	6	1	1	3
16	1	6	2	1	2
17	2	2	1	2	3
18	2	5	2	3	1
19	2	1	1	1	1
20	2	2	2	2	2
21	6	3	7	4	5
22	6	2	6	1	6
23	2	2	2	2	1
24	2	2	2	2	1
25	3	4	4	3	2
26	4	4	2	2	3
27	2	3	3	2	1
28	2	2	2	2	2
Total	80	96	75	71	65
Means	2.8571	3.4286	2.6786	2.5357	2.3214

Product : *Corn flavoured snack*

Panellists	Overall Preference	Overall Appearance	Flavour	Aroma	Colour
1	4	4	3	3	4
2	7	7	6	7	6
3	4	1	2	3	1
4	4	5	2	2	3
5	6	3	6	6	2
6	2	2	3	2	3
7	1	3	2	1	3
8	2	3	2	2	3
9	4	5	4	3	4
10	2	3	2	5	4
11	2	3	2	1	3
12	2	3	2	2	3
13	2	5	2	2	2
14	3	5	6	3	4
15	1	6	2	1	4
16	1	6	1	1	2
17	3	2	3	1	4
18	1	5	1	1	5
19	6	1	6	3	3
20	4	2	4	6	4
21	5	3	5	5	4
22	3	2	7	5	3
23	3	2	3	4	2
24	3	2	3	3	2
25	2	4	3	2	3
26	4	4	5	4	4
27	2	3	3	1	2
28	1	2	2	2	2
Total	84	96	92	81	89
Means	3.0000	3.4286	3.2857	2.8929	3.1786

[1)] 7 points hedonic scale, where: 1 = Like very much; 2 = Like moderately; 3 = Like slightly; 4 = Neither like nor dislike; 5 = Dislike slightly; 6 = Dislike moderately; 7 = Dislike very much

Appendix 6.10 Analysis of variance and Tukey's honestly significant different test for each product attribute

Colour

Analysis of variance

Source of Variation	SS	df	MS	F	P-value	F-crit (5%)
Panellists	50.1130	27	1.8560	1.0275	0.4374	1.5685
Samples	115.9821	5	23.1964	12.8420*	3.23e-10	
Error	243.8511	135	1.8063			
Total	409.9464	167				

Tukey's honestly significant different test test

Product code[1)]	356	241	935	689	723	538
Total	133	107	73	76	65	89
Means[2)]	4.7500[a]	3.8214[ab]	2.6071[c]	2.7142[c]	2.3214[c]	3.1785[bc]

Overall appearance

Analysis of variance

Source of Variation	SS	df	MS	F	P-value	F-crit (5%)
Panellists	73.7857	27	2.7328	1.5290	0.0604	1.5686
Samples	76.0476	5	15.2095	8.5098*)	5.01e-07	
Error	241.2857	135	1.7873			
Total	391.1190	167				

Tukey's honestly significant different test test

Product code[1)]	356	241	935	689	723	538
Total scores	130	96	78	79	75	96
Means[2)]	4.6428[a 3)]	3.4285[b]	2.7857[b]	2.8214[b]	2.6785[b]	3.4285[b]

Appendix 6.10 (Cont.) Analysis of variance and Tukey's honestly significant different test for each product attribute

Aroma

Analysis of variance

Source of Variation	SS	df	MS	F	P-value	F-crit (5%)
Panellists	89.5	27	3.3148	1.8335	0.0130	1.5686
Samples	23.2619	5	4.6524	2.5733	0.0294	
Error	244.0714	135	1.8079			
Total	356.8333	167				

Tukey's honestly significant different test test

Product code[1)]	356	241	935	689	723	538
Total	105	92	85	84	71	81
Means[2)]	$3.7500^{a\ 3)}$	3.2857^{ab}	3.0357^{ab}	2.5351^{ab}	2.3714^{b}	2.8929^{ab}

Flavour

Analysis of Variance

Source of Variation	SS	df	MS	F	P-value	F-crit (5%)
Panellists	99.2083	27	3.6744	1.9322	0.0077	1.5686
Samples	34.7441	5	6.9488	3.6536	0.0039	2.2813
Error	256.7560	135	1.9019			
Total	390.7083	167				

Tukey's honestly significant different test test

Product code[1)]	356	241	935	689	723	538	
Total	86	100	84	60	75	92	
Means[2)]	$3.0714^{ab\ 3)}$	3.5714^{a}	3.0000^{ab}		2.1429^{b}	2.6786^{ab}	3.2857^{a}

Appendix 6.10 (Cont.) Analysis of variance and Tukey's honestly significant different test for each product attribute

Overall preference

Analysis of Variance

Source of Variation	SS	df	MS		F	P-value	F-crit (5%)
Panellists	86.0179	27	3.1858	1.8623	0. 112	1.5686	1.5686
Samples	39.8869	5	7.9774	4.6632	0. 006	2.2813	
Error	230.9464	135	1.7107				
Total	356.8512	167					

Tukey's honestly significant different test test

Product code[1]	356	241	935	689	723	538
Total	107	104	78	70	80	84
Means[2]	3.8214^{a}[3]	3.7143^{ab}	2.785^{bc}	2.5000^{c}	2.8571^{abc}	3.0000^{abc}

[1] 356 = cheese flavour
241 = chicken flavour
935 = barbecue flavour
689 = spicy flavour
723 = savoury flavour
538 = corn flavour

[2] A lower mean indicates a higher preference score (1= like very much; 7 = dislike very much)

[3] different letter at the same line indicates significantly difference on treatments ($P<0.05$)

Appendix 7.1 Questionnaire form for final consumer product testing written in bahasa Indonesia

PENGUJIAN PRODUK JADI

Kode : ....

> Hai, saya Yuly Indrawati. Saya mahasiswa jurusan Teknologi Pangan di Massey University, Selandia Baru. Saya sedang mengadakan penelitian dan pengembangan mengenai produk snak yang sesuai dengan citarasa masyarakat di Indonesia. Produk snak dalam penelitian saya ini adalah makanan kecil sejenis Chiki, Jetz atau Cheetos, yang bahasa tekniknya disebut *extruded snack.* Produk yang akan saya hadirkan adalah hasil pengembangan produk yang telah melewati beberapa tahap uji rasa oleh orang-orang Indonesia di Selandia Baru. Untuk tahap akhir produk, snak ini harus dievaluasi oleh calon konsumen yang ditargetkan di Indonesia. Oleh karena itu, saya mohon bantuan dari saudara/i untuk berpartisipasi didalam testing ini.
> Bersama ini saya sediakan beberapa pertanyaan untuk menampung pendapat anda mengenai produk snak ini yang mungkin akan diproduksi dan dipasarkan di Indonesia. Informasi yang anda berikan akan diberlakukan secara konfidensial/rahasia. Tidak ada jawaban benar atau salah dalam pengisian kuesioner ini, akan tetapi jawaban yang paling sesuai dengan sikap dan citarasa anda sangat diharapkan.

Bagian I

1. **Anda menerima sebuah daftar kuesioner dan 4 macam sampel (kode ....; ....; ....; dan ....).**

   Silahkan sampel-sampel tersebut dibuka dan diuji rasa sesuai dengan letak urutan nomer kode di atas (lihat kode di dalam kurung). Tentukan urutan sampel yang anda sukai dan tulis nomer kodenya pada tempat yang tersedia.
   Anda diperbolehkan mencoba sampel-sampel tersebut lebih dari satu kali sampai anda yakin akan jawaban anda. Untuk menghindari bercampurnya rasa antar sampel, berkumurlah dengan air yang tersedia setiap kali anda mencoba sampel yang berbeda.

	Kode Produk
Ranking 1 (sampel yang paling disukai)	________
Ranking 2	________
Ranking 3	________
Ranking 4 (sampel yang paling kurang disukai)	________

2. **Tolong sebutkan karakteristik-karakteristik/ciri-ciri yang anda sukai dan yang tidak disukai dari masing-masing sampel sesuai dengan kode produknya. (Setelah mempertimbangkan rasa, warna, kerenyahan, penampilan, dll).**

Kode Produk	ciri-ciri yang disukai	ciri-ciri yang tidak disukai
Mis :123	warnanya yang kuning kecoklatan	kurang renyah , bau menyengat
237	________	________
	________	________
	________	________
358	________	________
	________	________
	________	________
495	________	________
	________	________
	________	________
619	________	________
	________	________
	________	________

Terima kasih atas bantuan anda, anda dipersilahkan untuk menunggu tes bagian II
(Beritahukan petugas bahwa anda telah menyelesaikan bagian I)

Appendix 7.1 (Cont.) Questionnaire form for final consumer product testing written in bahasa Indonesia

PENGUJIAN PRODUK JADI Kode : ....

Lengkapilah daftar kuesioner ini dengan menggunakan **sampel no.358.**

BAGIAN II
Petunjuk :
Berilah tanda (√) dalam kurung yang telah disediakan di depan jawaban anda dan informasi selengkap mungkin pada tempat yang disediakan.

1. Seringkah anda mengkonsumsi produk snak (segala macam produk snak)?
   (____) lebih dari 4 kali seminggu
   (____) 2 - 4 kali seminggu
   (____) sekali seminggu
   (____) 2 - 3 kali sebulan
   (____) kurang dari satu kali dalam sebulan
   (____) tidak pernah, sejak kapan ____________________

2. Apakah anda senang mengkonsumsi extruded snack, seperti Chiki, Taro, Cheetos, dll ?
   (____) Ya
   (____) Tidak,jelaskan mengapa anda tidak senang mengkonsumsi extruded snack ____________________
   ____
   ____
   ____

3. Apa merek dari extruded snak yang paling sering anda santap ? (jika mungkin sebutkan juga jenis rasanya)
   ____
   ____
   ____
   ____

4. Adakah ciri-ciri/karakteristik-karakteristik dari extruded snak yang anda sukai dan yang tidak anda sukai ? *(berikan tanda (√) sebanyak mungkin/lebih dari satu dan berikan contoh dari produk/merek yang mempunyai sifat karakteristik yang anda sukai atau tidak sukai tersebut)*

Sebagai petunjuk (beberapa merek-merek yang ada di pasaran) :

- Chiki ball	- Chiro	-Smax rice cracker
- Chiki net	- Double decker	- Happy tos
- Cheetos	- Taro (corn chip, rice chip)	- Gizanda
- Trampito	- Tato	- Master pauw
- Jetz	- Serena rice cracker	

Ciri-ciri yang *disukai*	**Contoh dari produk/merek dan jenis rasanya**
(____) rasa/flavour	____________________
(____) renyah	____________________
(____) warna	____________________
(____) bentuk	____________________
(____) harga	____________________
(____) familiar dengan snak yang akan disantap	____________________
(____) berat produk dalam kemasan	____________________
(____) desain kemasan	____________________
(____) informasi kandungan dalam produk	____________________
(____) menggunakan bahan baku yang halal	____________________
(____) hygiene/ tidak ada effek sampingan setelah mengkonsumsi	____________________
(____) karakteristik lain yang disukai	____________________
	____________________

Appendix 7.1 (Cont.) Questionnaire form for final consumer product testing written in bahasa Indonesia

Ciri-ciri yang *tidak disukai* produk/merek dan jenis rasanya	**Contoh dari**
(____) rasa/flavour	____________________
(____) warna	____________________
(____) produk lengket di mulut	____________________
(____) lengket di tangan ketika menggengam	____________________
(____) produk terlalu berminyak	____________________
(____) harga	____________________
(____) desain kemasan	____________________
(____) merasa haus setelah makan produk tersebut	____________________
(____) karakteristik lain yang tidak disukai	____________________
	____________________
	____________________

Bacalah deskripsi di bawah ini untuk memperjelas produk snak yang dimaksud dalam penelitian ini

> Sebuah produk extruded snack telah dikembangkan di Massey University, Selandia Baru dan direncanakan untuk diproduksi dan dipasarkan di Indonesia. Produk ini terbuat dari campuran kacang kedelai yang berkadar lemak rendah, jagung dan beras sebagai bahan dasar. Karena terbuat dari bahan-bahan pilihan, snak ini sangat bergizi, menyehatkan dan tinggi kandungan proteinnya sehingga memiliki nilai tambah melebihi produk-produk sejenis yang telah ada di pasaran.
>
> Kandungan protein yang tinggi pada snak ini diperoleh dari kacang kedelai. Disamping itu snak ini tidak mengandung kolesterol dan mengandung lemak nabati yang rendah yang sangat baik untuk kesehatan dan diet. Walaupun sedikit mengandung lemak, kelezatan dan kegurihan produk tetap terjamin. Adanya kandungan beras dalam snak membuat produk ini sangat renyah. Snak ini juga mempunyai rasa spicy yang enak dan sesuai dengan citarasa Indonesia. Sangat sesuai untuk disantap kapan saja dan di mana saja.

5. Sukakah anda mengkonsumsi produk extruded snack yang mengandung kacang kedelai dengan kadar lemak rendah sesuai dengan deskripsi produk di atas?
   (____) Ya
   (____) Tidak

   Jelaskan alasan-alasan anda, mengapa anda suka *atau* tidak suka mengkonsumsi snak tersebut

   ____
   ____
   ____
   ____

6. Dengan memperhatikan sampel no. 358 yang tersedia, bagaimana pendapat anda terhadap **warna snak** tersebut ?
   (____) sangat suka
   (____) suka
   (____) agak suka
   (____) antara suka dan tidak suka
   (____) agak tidak suka
   (____) tidak suka
   (____) sangat tidak suka

7. Bagaimana pendapat anda terhadap **penampilan dari sampel** tersebut, setelah mempertimbangkan warna, bentuk, ukuran snak, dll ?
   (____) sangat suka
   (____) suka
   (____) agak suka
   (____) antara suka dan tidak suka
   (____) agak tidak suka
   (____) tidak suka
   (____) sangat tidak suka

Appendix 7.1 (Cont.) Questionnaire form for final consumer product testing written in bahasa Indonesia

8. Setelah mencium aroma sampel, bagaimana pendapat anda terhadap **aroma produk** ?
(____) sangat suka
(____) suka
(____) agak suka
(____) antara suka dan tidak suka
(____) agak tidak suka
(____) tidak suka
(____) sangat tidak suka

9. Setelah mencicipi sampel tersebut, bagaimana pendapat anda terhadap **citarasa produk** ?
(____) sangat suka
(____) suka
(____) agak suka
(____) antara suka dan tidak suka
(____) agak tidak suka
(____) tidak suka
(____) sangat tidak suka

10. **Secara keseluruhan** (*setelah mempertimbangkan warna, penampilan, aroma dan rasa dari sampel*), bagaimana pendapat anda terhadap snak tersebut ?
(____) sangat suka
(____) suka
(____) agak suka
(____) antara suka dan tidak suka
(____) agak tidak suka
(____) tidak suka
(____) sangat tidak suka

11. Ciri-ciri apa dari produk tersebut yang anda sukai dan tidak sukai ?

Ciri-ciri yang disukai	Ciri-ciri yang tidak disukai
____________	____________
____________	____________
____________	____________
____________	____________
____________	____________
____________	____________

12. Jika produk seperti sampel ini ada di pasaran, apakah anda akan membeli produk ini ?
(____) Ya
(____) Tidak, jelaskan mengapa anda tidak ingin membeli produk ini
____
____
____
____

13. Menurut pendapat anda, berapa harga yang pantas untuk produk sampel 358 ?
(____) jauh lebih tinggi dari harga yang biasanya anda bayar
(____) sedikit lebih tinggi dari harga yang biasanya anda bayar
(____) sama dengan harga yang biasanya anda bayar
(____) sedikit lebih rendah dari harga yang biasanya anda bayar
(____) jauh lebih rendah dari harga yang biasanya anda bayar

Appendix 7.1 (Cont.) Questionnaire form for final consumer product testing written in bahasa Indonesia

14. Jika harga produk ini di pasaran Rp 350/20g kemasan, berapa kali kemungkinan anda akan membeli produk ini?
(____) lebih dari 4 kali seminggu
(____) 2 - 4 kali seminggu
(____) sekali seminggu
(____) 2 - 3 kali sebulan
(____) sekali sebulan
(____) kurang dari satu sebulan

15. Jika anda membeli produk ini, berapa berat produk dalam sebuah kemasan yang kira-kira akan anda senangi ? (berat rata-rata produk dalam sebuah kemasan kecil di pasaran adalah 20 g)
(____) 20 - 25 g dalam satu kemasan
(____) 45 - 50 g dalam satu kemasan
(____) 70 - 75 g dalam satu kemasan
(____) 150 - 200 g dalam satu kemasan
(____) lebih dari 250 g dalam satu kemasan
(____) lain-lain, jelaskan
____
____

16. Anda berada di kelompok umur :
(____) 15 - 18 tahun
(____) 19 - 23 tahun
(____) 24 - 30 tahun
(____) lebih dari 30 tahun

17. Jenis kelamin :
(____) pria
(____) wanita

18. Pekerjaan :
(____) mahasiswa
(____) staf universitas
(____) lain-lain, sebutkan ______________________

Terima kasih atas bantuan anda

Appendix 7.2. Questionnaire form for final consumer product testing written in English

FINAL PRODUCT TESTING Code : ......

Hi, my name is Yuly. I am a food technology student at Massey University, New Zealand. My project is to develop a snack product for Indonesian consumers. The snack product in this case is an extruded snack. Examples of extruded snacks are Chiki, Jetz and Cheetos. The product was developed and had been tested by Indonesian people in New Zealand. For the final product testing, the snack should be evaluated in Indonesia. Therefore, could you please help me to participate in this testing. I would like you to fill the questionnaire so that it can provide information on extruded snack development for production and marketing in Indonesia. The information will be treated confidentially. There is no right or wrong answers in this testing, however the answers that best reflect your attitudes would be appreciated.

PART I

1. **You have received a questionnaire and four samples (i.e. code ....; ....; ....and ....).**

   Please open the samples and taste them in the order of the product code above (in the bracket). Rank them due to your preference and write the product code on the provided space.
   You may like to taste the product several times before you make a decision for your preference.
   Please ensure you rinse your mouth with water before tasting each different sample.

	Product code
Rank 1 (the most preferred sample)	________
Rank 2	________
Rank 3	________
Rank 4 (the least preferred sample)	________

2. **Please list the characteristics of each sample that you like and dislike**

Product Code	Favourable characteristics	Unfavourable characteristics
237	________	________
	________	________
	________	________
	________	________
358	________	________
	________	________
	________	________
	________	________
495	________	________
	________	________
	________	________
	________	________
619	________	________
	________	________
	________	________
	________	________

Thank you for your cooperation, please wait for the second part

Appendix 7.2. (Cont.) Questionnaire form for final consumer product testing written in English

FINAL PRODUCT TESTING Code : ....

PART II

Now could you complete this questionnaire using samples no. 358.

<u>Instruction</u> :

Please place a tick (√) in the bracket in front of your answer. Where I have left a space for you to write, please give as detailed an answer as possible.

1. How often do you consume snack products (any types of snack)?
   (____) more than 4 times a week
   (____) 2 - 4 times a week
   (____) once a week
   (____) 2 - 3 times a month
   (____) less than once a month
   (____) never, since when ____________________

2. Do you like eating extruded snacks ?
   (____) Yes
   (____) No, please specify any reasons why you do not like eating extruded snack
   ____
   ____
   ____
   ____

3. What brands of the extruded snack do you consume the most often ? (if possible specify also the flavour)
   ____
   ____
   ____
   ____

4. What are the extruded snack characteristics that you like and dislike ? *(Please tick as many as you want and give the examples of products/brands that you like or dislike)*

The following hints are the extruded snack brands currently available in the market

- Chiki ball	- Chiro	- Smax rice cracker
- Chiki net	- Double decker	- Happy tos
- Cheetos	- Taro (corn chip, rice chip)	- Gizanda
- Trampito	- Tato	- Master pauw
- Jetz	- Serena rice cracker	

<u>Favourable characteristics</u>	<u>Examples of products/brands</u>
(____) flavour	____________________
(____) crispiness	____________________
(____) colour	____________________
(____) shape	____________________
(____) price	____________________
(____) familiarity with the product	____________________
(____) packet size	____________________
(____) packaging design	____________________
(____) nutritional information	____________________
(____) halal ingredients	____________________
(____) hygiene/ no nouseous effect after eating	____________________
(____) others	____________________
	____________________
	____________________

Appendix 7.2. (Cont.) Questionnaire form for final consumer product testing written in English

Unfavourable characteristics	Examples of products/brands
(____) flavour	____________________
(____) colour	____________________
(____) sticky in the mouth	____________________
(____) sticky on the hand while holding	____________________
(____) product is oily	____________________
(____) price	____________________
(____) packaging	____________________
(____) feel thirsty after eating	____________________
(____) others	____________________
	____________________
	____________________

Please read the following description

> An extruded snack is developed at Massey University, New Zealand. This snack is made from low fat soya bean, corn and rice. The product will be produced in Indonesia for Indonesian consumers and have several advantages over other products in the market.
>
> This extruded snack is nutritious, healthy and contains a higher protein, as it is made from selected quality corn, rice and soya. A higher protein is obtained from the presence of soya bean. The snack contains low fat and no cholesterol. Although it contains low fat, the product is still delicious and crunchy. The addition of rice makes a very crispy product. The snack has a nice spicy flavour which is developed for Indonesian taste. It is a fun to eat it anytime and anywhere.

5. Would you consume an extruded snack product contains low fat soya bean as described above ?
   (____) Yes
   (____) No

   Please specify the reasons why you would or would not consume that snack

   ____
   ____
   ____
   ____
   ____

6. *Please observe the snack provided (no.358)*, how do you like its colour?
   (____) like very much
   (____) like
   (____) like moderately
   (____) neither like nor dislike
   (____) dislike moderately
   (____) dislike
   (____) dislike very much

7. How do you like the sample's appearance ?
   (consider the colour, shape, coating, etc)
   (____) like very much
   (____) like
   (____) like moderately
   (____) neither like nor dislike
   (____) dislike moderately
   (____) dislike
   (____) dislike very much

Appendix 7.2. (Cont.) **Questionnaire form for final consumer product testing written in English**

8. *Please smell the product,* how do you like the aroma of the snack ?
(____) like very much
(____) like
(____) like moderately
(____) neither like nor dislike
(____) dislike moderately
(____) dislike
(____) dislike very much

9. *Please taste the snack,* how do you like its flavour ?
(____) like very much
(____) like
(____) like moderately
(____) neither like nor dislike
(____) dislike moderately
(____) dislike
(____) dislike very much

10. In overall (after considering the colour, appearance, aroma and flavour of the sample), how do you like the snack ?
(____) like very much
(____) like
(____) like moderately
(____) neither like nor dislike
(____) dislike moderately
(____) dislike
(____) dislike very much

11. What are the things that you like or dislike about the product ?

Favourable characteristics	Unfavourable characteristics
____________________	____________________
____________________	____________________
____________________	____________________
____________________	____________________
____________________	____________________
____________________	____________________

12. If this sample is available in the market, will you buy it ?
(_____) Yes
(_____) No, please specify why you will not buy the product
____
____
____
____
____

13. At what price would you prepare to pay ?
(_____) very much higher than the one you normally buy
(_____) slightly higher than the one you normally buy
(_____) the same price as the one you normally buy
(_____) slightly lower than the one you normally buy
(_____) very much lower than the one you normally buy

14. If the product price in the market is Rp. 350/ 20g packet, how often do you think you would buy this snack ?
    (____) more than 4 times a week
    (____) 2 - 4 times a week
    (____) once a week
    (____) 2 - 3 times a month
    (____) once a month
    (____) less than once a month

15. What packet size would you choose if you buy this snack ?(20g is the average weight of the small extruded snack packet)
    (____) 20 - 25 g in each packet
    (____) 45 - 50 g in each packet
    (____) 70 - 75 g in each packet
    (____) 150 - 200 g in each packet
    (____) more than 250 g in each packet
    (____) others, please specify ____________________

16. Sex : (_____) Male (_____) Female

17. Age group :
    (_____) 15 - 18 years (_____) 24 - 30 years
    (_____) 19 - 23 years (_____) more than 30 years

18. Occupation : (_____) student
    (_____) university staff member
    (_____) others, please specify
    ____

Thank you for your cooperation

Appendix 7.3. Summary of results from the final product testing

PART I.

A ranking test result between the developed snack and commercial products

Extruded snack eater group

Brands	Rank				Total row	Weighted sum[1] (Σ(x.n))	Weighted mean[1] (Σ(x.n)/total panellists)
	1	2	3	4			
Chiki	20	25	26	33	104	354	3.4
New product	12	25	26	41	104	240	2.3
Cheetos	60	29	12	3	104	230	2.2
Bigun	12	25	40	27	104	216	2.1
Total	104	104	104	104			

df = 9 ; χ^2 = 107.39 (P=0.00)

[1] x = number of participants on each rank
n = factor for the preference rank (n = 4 for the most preference; n = 1 for the least preference)
Higher value indicates higher preference

Non-extruded snack eater group

Brands	Rank				Total row	Weighted sum[1] (Σ(x.n))	Weighted mean[1] (Σ(x.n)/total panellists)
	1	2	3	4			
Chiki	9	11	9	14	43	142	3.3
New product	5	13	9	16	43	101	2.3
Cheetos	24	11	5	3	43	94	2.2
Bigun	5	8	20	10	43	93	2.2
Total	43	43	43	43			

df = 9 ; χ^2 = 45.44 (P=0.00)

[1] x = number of participants on each rank
n = factor for the preference rank (n = 4 for the most preference; n = 1 for the least preference)
Higher value indicates higher preference

PART II.

Question 1. Frequency of any snack products consumption

Frequency	Participants				Total row (people)(%)	
	extruded snack eater		non-extruded snack eater			
	(people)	(%)	(people)	(%)		
More than 4 times a week	11	(7.5)	2	(1.4)	13	(8.8)
2 - 4 times a week	17	(11.6)	2	(1.4)	19	(12.9)
Once a week	19	(12.9)	3	(2.0)	22	(15.0)
2 - 3 times a month	31	(21.1)	6	(4.1)	37	(25.2)
Less than once a month	19	(12.9)	22	(14.6)	41	(27.9)
Never	7	(4.8)	8	(5.4)	15	(10.2)
Total column	104	(70.8)	43	(28.9)	147	(100)

df = 5, χ^2 = 26.06 (P=0.00)

Question 2. Do you like eating extruded snacks ?

Responds	Participants (people)	(%)
Yes	104	(70.8)
No	43	(29.2)
Total	147	(100)

df = 1; χ^2 = 25.31 (P=0.00)

Question 3. Favourable brand by the consumers

Brands	Participants[1)]				Total rows (people) (%)	
	Extruded snack eater (people) (%)		Non-extruded snack eater (people) (%)			
Chiki	47	(24.1)	6	(3.1)	53	(27.2)
Cheetos	48	(24.6)	15	(7.7)	63	(32.3)
Chitato	12	(6.2)	3	(1.5)	15	(7.7)
Taro	29	(14.9)	3	(1.5)	32	(16.4)
Happy tos	5	(2.6)	3	(1.5)	8	(4.1)
Gizanda	4	(2.1)	0	(0.0)	4	(2.1)
Jetz	10	(5.1)	2	(1.0)	12	(6.1)
Serena	2	(1.0)	0	(0.0)	2	(1.0)
Others	5	(2.6)	1	(0.5)	6	(3.1)
Total column	162	(83.2)	33	(16.8)	195	(100)

df = 8; χ^2 = 8.34 (P=0.31)

1) participants could mention the brands as much as they aimed. The flavours they preferred were cheese, corn, chicken, chocolate, sea weed and barbecue.

Question 4A. Favourable characteristics in the extruded snacks

Favourable characteristics	Participants[1)]				Total row (people) (%)	
	extruded snack eater (people) (%)		non-extruded snack eater (people) (%)			
Favourable flavour	89	(11.2)	31	(3.9)	120	(15.1)
Crispiness	96	(12.1)	28	(3.5)	124	(15.6)
Colour	57	(7.2)	18	(2.3)	75	(9.5)
Shape	61	(7.7)	17	(2.1)	78	(9.8)
Low price	60	(7.6)	18	(2.3)	78	(9.9)
Familiarity with the product	23	(2.9)	9	(1.1)	32	(4.0)
Packet size	21	(2.6)	9	(1.1)	30	(3.7)
Packaging design	48	(6.1)	14	(1.8)	62	(7.9)
Nutritional information	44	(5.5)	13	(1.6)	57	(7.2)
Halal ingredients	49	(6.2)	12	(1.5)	61	(7.7)
Hygiene/no nauseous effect after eating	53	(6.7)	16	(2.0)	69	(8.7)
Others[2)]	4	(0.5)	3	(0.4)	7	(0.9)
Total column	605	(76.3)	188	(23.7)	793	(100)

df = 11; χ^2 = 3.62 (P = 0.98)

1) participants could tick the characteristics as much as they aimed.

2) included legalization approval, advertisement, accessible, aroma

Question 4B. Unfavourable characteristics in the extruded snacks

Unfavourable characteristics	Participants[1)]				Total row (people) (%)	
	extruded snack eater (people)	(%)	non-extruded snack eater (people)	(%)		
Unfavourable flavour	39	(9.2)	15	(3.6)	54	(12.8)
Colour	26	(6.2)	6	(1.4)	32	(7.6)
Sticky in the mouth	55	(13.0)	15	(3.6)	70	(16.6)
Sticky on the hand while holding	51	(12.1)	16	(3.8)	67	(15.9)
Product is oily	47	(11.1)	15	(3.6)	62	(14.7)
High price	26	(6.1)	4	(1.0)	30	(7.1)
Packaging	10	(2.4)	2	(0.5)	12	(2.9)
Feeling thirsty after eating	67	(15.9)	20	(4.8)	87	(20.7)
Others[2)]	5	(1.2)	2	(0.5)	7	(1.7)
Total column	326	(77.3)	95	(22.6)	421	(100)

df = 8, χ^2 = 3.174 (P=0.92)

1) participants could tick the characteristics as much as they aimed.

2) soggy, no expired date, misleading package information, preservative additive content

Question 5. Would you consume an extruded snack product contains low fat soy bean ?

Responds	Participants				Total row (people) (%)	
	extruded snack eater (people)	(%)	non-extruded snack eater (people)	(%)		
Yes	74	(50.34)	32	(21.77)	106	(72.11)
No	30	(20.41)	11	(7.48)	41	(27.89)
Total column	104	(70.75)	43	(29.25)	147	(100)

df = 1, χ^2 = 0.16 (P=0.69)

Question 6-10 (A). New product acceptability towards colour, overall appearance, aroma, taste, overall preference by extruded snack eater

Acceptability	Hedonic scores[1] (people) (%)							Total row	Weighted sum[2] (Σ(x.n))	Weighted mean[2] (Σ(x.n)/total panellists)
	1	2	3	4	5	6	7			
Colour	6 (1.2)	28 (5.4)	18 (3.5)	13 (2.5)	16 (3.1)	21 (4.0)	2 (0.4)	104 (20)	444	4.3
Overall appearance	4 (0.8)	32 (6.2)	21 (4.0)	17 (3.3)	17 (3.3)	11 (2.1)	2 (0.4)	104 (20)	468	4.5
Aroma	5 (1.0)	25 (4.8)	18 (3.5)	16 (3.1)	11 (2.1)	21 (4.0)	8 (1.5)	104 (20)	422	4.1
Taste	5 (1.0)	28 (5.4)	28 (5.4)	15 (2.9)	5 (1.0)	20 (3.9)	3 (3.1)	104 (20)	461	4.4
Overall preference	5 (1.0)	24 (4.6)	32 (6.2)	15 (2.9)	7 (1.4)	20 (3.9)	1 (0.2)	104 (20)	461	4.4
Total column	25 (4.8)	137 (26.4)	117 (22.5)	76 (14.6)	56 (10.8)	93 (17.9)	16 (3.1)	520 (100)		

df = 24, χ^2 = 32.85 (P=0.11)

[1] Hedonic scores : 1 = Like very much; 2 = Like moderately; 3 = Like slightly; 4 = Neither like nor dislike; 5 = Dislike slightly; 6 = Dislike moderately; 7 = Dislike very much

[2] x = number of participants on each rank
n = factor for the degree of acceptability (n = 7 for like very much in hedonic score; n = 1 for dislike very much in hedonic score)
Higher value indicates higher acceptability

Question 6-10 (B). New product acceptability towards colour, overall appearance, aroma, taste, overall preference by non-extruded snack eater

Acceptability	Hedonic scores[1] (people) (%)							Total row	Weighted sum[2] (Σ(x.n))	Weighted mean[2] (Σ(x.n)/total panellists)
	1	2	3	4	5	6	7			
Colour	4 (1.9)	16 (7.4)	7 (3.3)	5 (2.3)	4 (1.9)	6 (2.8)	1 (0.5)	43 (20)	204	4.7
Overall appearance	5 (2.3)	16 (7.4)	9 (4.2)	2 (0.9)	5 (2.3)	6 (2.8)	0 (0.0)	43 (20)	211	4.9
Aroma	0 (0.0)	11 (5.1)	10 (4.6)	9 (4.2)	6 (2.8)	7 (3.3)	0 (0.0)	43 (20)	184	4.3
Taste	3 (1.4)	11 (5.1)	8 (3.7)	5 (2.3)	8 (3.7)	7 (3.3)	1 (0.5)	43 (20)	186	4.3
Overall preference	3 (1.4)	9 (4.2)	14 (6.5)	7 (3.3)	5 (2.3)	5 (2.3)	0 (0.0)	43 (20)	198	4.6
Total column	15 (7.0)	63 (29.3)	48 (22.3)	28 (13.0)	28 (13.0)	31 (14.4)	2 (1.0)	215 (100)		

df = 24, χ^2 = 20.93 (P=0.17)

[1] Hedonic scores : 1 = Like very much; 2 = Like moderately; 3 = Like slightly; 4 = Neither like nor dislike; 5 = Dislike slightly; 6 = Dislike moderately; 7 = Dislike very much

[2] x = number of participants on each rank
n = factor for the degree of acceptability (n = 7 for like very much in hedonic score; n = 1 for dislike very much in hedonic score)
Higher value indicates higher acceptability

Question 11. Favourable and unfavourable characteristics of the new product

Favourable characteristics : crispy
unique flavour (a mixture among hot, spicy, salty and a bit sweet)
tasty
nice aftertaste
shape

Unfavourable characteristics : oily
sticky in teeth
dark in colour
monosodium glutamate flavour.

Question 12. If this sample is available in the market, will you buy it ?

Responds	Participants				Total row (people) (%)	
	extruded snack eater (people) (%)		non-extruded snack eater (people) (%)			
Yes	69	(46.9)	20	(13.6)	89	(60.5)
No	35	(23.8)	23	(15.7)	58	(39.5)
Total column	104	(70.7)	43	(29.3)	147	(100)

df = 1, χ^2 = 5.00 (P=0.25)

Question 13. Price prepared to pay by the consumers as the comparison with the product they currently purchase

Price prepared to pay compared to the currently purchasing price	Participants				Total row (people) (%)	
	extruded snack eater (people) (%)		non-extruded snack eater (people) (%)			
Very much higher	0	(0.0)	0	(0.0)	0	(0.0)
Slightly higher	3	(3.4)	3	(3.4)	6	(6.7)
Same price	31	(34.8)	13	(14.6)	44	(49.4)
Slightly lower	28	(31.5)	4	(4.5)	32	(36.0)
Very much lower	7	(7.9)	0	(0.0)	7	(7.9)
Total column	69	(77.5)	20	(22.5)	89	(100)

df = 3, χ^2 = 7.73 (P=0.05)

Question 14. Intention of buying frequency for the new product

Buying frequency	Participants				Total row (people) (%)	
	extruded snack eater (people) (%)		non-extruded snack eater (people) (%)			
More than 4 times a week	3	(3.4)	1	(1.1)	4	(4.5)
2 - 4 times a week	21	(23.6)	4	(4.5)	25	(28.1)
Once a week	13	(14.6)	6	(6.7)	19	(21.3)
2 - 3 times a month	18	(20.2)	9	(10.1)	27	(30.3)
Once a month	4	(4.5)	0	(0.0)	4	(4.5)
Less than once a month	10	(11.2)	0	(0.0)	10	(11.2)
Total column	69	(77.5)	20	(22.5)	89	(100)

df = 5, χ^2 = 7.41 (P=0.38)

Question 15. Packet size intended in buying the new product

Packet size (in each packet)	Participants				Total row (people) (%)	
	extruded snack eater (people) (%)		non-extruded snack eater (people) (%)			
20 - 25 g	40	(44.9)	13	(14.6)	53	(59.5)
45 - 50 g	13	(14.6)	4	(4.5)	17	(19.1)
70 - 75 g	3	(3.4)	1	(1.1)	4	(4.5)
150 - 200 g	7	(7.9)	0	(0.0)	7	(7.9)
More than 250 g	3	(3.4)	0	(0.0)	3	(3.4)
Others	3	(3.4)	2	(2.2)	5	(5.6)
Total column	69	(77.5)	20	(22.5)	89	(100)

df = 5, χ^2 = 3.94 (P=0.70)

Appendix 8.1 Ingredients for formulation 5 and processing conditions used on the single screw extruder experiment

Ingredients for formulation 5 :

Corn meal (Variety 3162)	59.6 %
Defatted soya flour	28 %
Rice flour	12 %
Baking soda	0.4 %

Trial Code	Feed rate (kg/hr)	Moisture ingredients (% wb)	Screw speed (rpm)	T1 (°C)	T2 (°C)	Ampersmeter (A)
S_1	11.38	15.37	880	89	168	6.6
S_2	13.01	15.37	880	90	168	6.5
S_3	17.89	15.37	880	89	168	6.5
S_4	11.38	16.23	880	90	168	6
S_5	13.01	16.23	880	90	169	6
S_6	17.89	16.23	880	90	168	6

Appendix 8.2 Formulation 5 manufactured using the twin screw extruder at different process conditions

Ingredients	Trial code[a)]		Process							
			Feed (kg/hr)	Moist. cont. (%)	Screw (rpm)	T1 (°C)	T2 (°C)	T3 (°C)	T4 (°C)	Torque (N.m)
Formulation 5	8	(T_1)	4.39	17	332	39	80	114	139	24.6
	13	(T_2)	4.55	17	301	40	75	116	160	19
	19	(T_3)	4.47	17	332	42	80	116	161	22.6
	22	(T_4)	4.47	16	304	40	80	113	140	27.5

a) Trial code similar to that used in product formulation (refers to Appendix 5.1)

Appendix 8.3 Format of questionnaire for sensory evaluation

PRODUCT TESTING

Date : ....
Name : ....

Part I

Please give a score to each sample on the blank that best reflects your preference to the expanded extrusion snack.

Scores : 1 = Like very much
2 = Like moderately
3 = Like slightly
4 = Neither like nor dislike
5 = Dislike slightly
6 = Dislike moderately
7 = Dislike very much

Please ensure you rinse your mouth with plain water, before testing the other sample.

Product codes	Colour	Overall appearance	Texture	Flavour	Overall preference
649	.....	.....	.....	.....	.....
813	.....	.....	.....	.....	.....

Part II

How crisp are the products ?

Please indicate the degree of crispiness by placing the following score next to the code of each sample

Scores : 1 = Much too crispy
2 = Slightly too crispy
3 = Just right
4 = Slightly too little crispiness
5 = Not crispy enough

Please ensure you rinse your mouth with plain water, before testing the other sample.

Product codes	Degree of crispiness
649	....
813	....

Please give comments on how the products' texture, appearance and flavour affect your overall preference :

Thank you for your cooperation

Appendix 8.4 Panellists' respond on sensory evaluation between twin screw extruder and single screw extruder

Product : *Twin screw extrudate*

Panellists (No.)	Overall preference[1)]	Flavour[1)]	Colour[1)]	Overall appearance[1)]	Texture[1)]	*Just right* test[2)]
1	3	2	1	1	1	4
2	3	2	3	1	1	5
3	2	2	2	3	1	4
4	1	1	2	2	1	3
5	2	2	2	3	2	4
6	3	3	3	2	2	2
7	3	4	2	2	3	1
8	1	1	2	2	1	3
9	6	5	2	3	2	3
10	2	3	2	3	2	1
11	1	1	2	2	3	3
12	2	3	4	3	2	2
13	2	1	2	1	1	5
14	3	3	1	2	2	2
15	2	2	2	2	2	4
16	1	2	1	3	3	2
17	1	1	1	1	2	2
18	1	1	1	1	2	4
19	3	3	2	1	1	3
20	5	6	3	4	3	4
21	2	2	2	5	3	3
22	3	3	3	3	3	4
23	5	3	2	2	2	5
24	2	3	1	1	2	2
25	6	6	2	2	4	1
26	2	1	2	2	2	5
27	2	3	2	3	3	4
28	3	4	2	2	4	4
29	1	1	1	2	1	3
30	4	5	2	2	1	5
31	3	4	2	3	4	4
32	4	5	2	2	1	5
33	1	5	6	1	1	1
Total	85	93	69	72	68	107
Mean	2.58	2.82	2.09	2.18	2.06	3.24
Variance	2.00	2.34	0.96	0.90	0.93	1.69

Product : *Single screw extrudate*

Panellists (No.)	Overall preference[1)]	Flavour[1)]	Colour[1)]	Overall appearance[1)]	Texture[1)]	*Just right* test[2)]
1	1	1	2	2	3	3
2	2	3	2	3	4	2
3	1	1	2	1	3	3
4	1	1	1	1	2	3
5	2	1	2	2	3	3
6	2	1	2	2	3	3
7	2	2	3	3	3	2
8	1	1	1	2	1	3
9	2	1	2	5	7	1
10	2	2	2	3	2	3
11	1	1	2	1	1	4
12	3	2	2	2	2	3
13	2	2	1	2	2	3
14	2	1	3	3	3	3
15	1	1	2	3	3	3
16	2	2	1	2	1	3
17	1	1	1	2	1	3
18	2	2	1	1	2	3
19	2	1	3	2	3	2
20	3	2	3	3	3	3
21	3	6	3	2	1	2
22	3	2	3	2	3	3
23	2	2	3	2	6	3
24	3	3	4	3	2	3
25	3	3	2	2	6	2
26	2	2	1	2	3	3
27	2	3	2	2	2	2
28	2	2	3	3	5	2
29	2	1	1	3	1	3
30	1	1	5	2	4	3
31	2	1	3	2	1	3
32	1	1	5	4	5	3
33	2	1	1	2	5	3
Total	63	57	74	76	96	91
Mean	1.91	1.73	2.24	2.30	2.91	2.76
Variance	0.46	1.08	1.19	0.72	2.59	0.31

1) 7 points hedonic scale, where 1 = like very much; 7 = dislike very much

2) 5 points *just right* scale, where 1 = much too crispy; 2 = slightly too crispy; 3 = just right; 4 = slightly too little crispiness; 5 = not crispy enough

Appendix 8.5 Relationship between degree of crispiness (*just right* test) versus texture preference (hedonic test) on single screw and on twin screw extruders

Single screw extruder

Panellists on each hedonic and *just right* scale		Texture preference on each hedonic scale[b] (people)							Total row
		1	2	3	4	5	6	7	
	1	-	1	1	-	1	1	-	4
Just right	2	2	2	2	-	-	-	-	6
scale[a]	3	4	1	1	-	-	-	1	7
(people)	4	1	2	6	-	1	-	-	**10**
	5	-	1	1	2	1	1	-	6
Total column		7	7	**11**	2	3	2	1	33

Twin screw extruder

Panellists on each hedonic and *just right* scale		Texture preference on each hedonic scale[b] (people)							Total row
		1	2	3	4	5	6	7	
	1	-	1	-	-	-	-	-	1
Just right	2	2	-	3	2	-	-	-	7
scale[a]	3	9	11	3	1	-	-	-	**24**
(people)	4	-	-	1	-	-	-	-	1
	5	-	-	-	-	-	-	-	-
Total column		**11**	**12**	7	3	-	-	-	33

a) indicates degree of crispiness (1 = much too crispy; 3 = just right; 5 = not crispy enough)

b) indicates degree of texture preference (1 = like very much; 4 = neither like or dislike; 7 = dislike very much)

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8.3 EXTRUDED SNACK DEVELOPMENT. A STUDY OF THE CORRELATION BETWEEN ITS PHYSICAL PROPERTIES AND CONSUMER ACCEPTABILITY

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A constrained mixture design was used to develop an extruded snack for the Indonesian market and to study the effect of ingredients and extrusion operating conditions on the extrudate physical properties and consumers acceptability.

The snack was manufactured using a co-rotating and intermeshing twin screw extruder with a constant feed rate. Ingredients included cornmeal (59.5%), defatted soya flour (10-28%), rice flour (2-20%), tapioca flour (0-10%) and baking soda (0.4%). Extrusion variables were screw speed (300-330 rpm), water addition (0.15-0.2 kg/hr) and temperature of the extruder barrel in the last section (140-160°C). The effect of ingredients and extrusion variables on the extrudate physical properties such as water absorption index (WAI), water solubility index (WSI), nitrogen solubility index (NSI), colour (L*, a*, b*), texture (breaking strength), moisture content and consumer acceptability was investigated. Results showed that an increase in rice flour increased extrudate water absorption index and breaking strength. In addition an increase in soya resulted in a decrease in water absorption index and the redness (a*) of the extrudate. Specific Mechanical Energy (SME), an extruder parameter, was calculated through torque measurements. Higher SME produced extrudates with lower breaking strength.