A QUANTITATIVE MODEL FOR THE DESIGN OF NUTRITIOUS AND ACCEPTABLE FOODS

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ABSTRACT

A quantitative model was developed for the systematic selection of raw materials for nutritious and acceptable Thai foods. The basis for the quantitative model was linear programming. Unlike most other applications of this technique which considered only nutritional needs, this model also took into account the consumer's requirements for an acceptable food. The development of the model formed part of a research programme in the Food Technology Department of Massey University which is investigating quantitative product development techniques.

The linear programming model was used firstly to select raw material mixes which would satisfy the daily nutritional requirements of the Thai people. Selection was made from a list of 151 available raw materials - 144 indigenous Thai raw materials and 7 New Zealand dairy products. The requirements for 26 nutrients were satisfied. These included protein, fat, calories, fibre, 3 minerals, 9 vitamins and 10 essential amino acids. The lack of specific upper limits on most of the nutrients resulted in solutions with a gross nutritional imbalance. Recent investigations indicate that such imbalances may be detrimental to human health and it is suggested that a more satisfactory diet is one where all nutrients are balanced, at or near their lower requirement levels. Considerable problems exist in achieving a balanced diet using range constraints in the linear programme due to the probability of solution infeasibilities.

Goal programming, an extension of linear programming, has been used in other fields of research to minimize the deviation of solution variables from specific goals. This technique showed potential in attaining a balanced nutritional diet where the goals represented the requirements for specific nutrients. A goal programming model was devised which firstly achieved a balance of essential amino acids as close to that of egg protein as possible. Secondly, a solution was obtained where all 26 nutrients were at

the 'optimum' balance. The achievement of a balanced nutritional diet resulted in a large increase in cost and indicated the importance of careful definition of the requirements for nutritional balance in future research where cost minimization is a priority.

The raw materials selected by both goal and linear programming were totally unacceptable as ingredients in a Thai food dish without extensive processing to change both flavour and texture of the mixture. It was more logical to provide a procedure for raw material selection on the basis of their combined acceptability in a Thai food dish. Nonmetric multidimensional scaling was used to derive a 3 dimensional configuration of 40 raw materials from consumer information on the use of these raw materials in Thai food dishes. The axes of this space represented the dominant properties of raw materials in determining food dish acceptability. An ideal point was located in this space. This point was defined as the 'optimum' combination of raw material properties required in a Thai food dish.

Nonmetric multidimensional scaling provided the basis for derivation of metric scale values for the 40 raw materials and the ideal point. These values were used to derive a linear function relating raw materials to food dish acceptability. This function was used in the linear programming model together with nutritional constraints to provide a systematic method of raw material selection for nutritious and acceptable Thai food dishes. The raw material mixes selected by this model showed a marked improvement over those chosen by the linear programme subject to only nutritional constraints.

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PREFACE

Food product development is the procedure by which raw materials are selected and then combined through a system of processing into a food product acceptable to the final consumer. For many years, product development has been based more in intuition than on objective judgement. There has, however, been a gradual infiltration of quantitative techniques in recent years in an attempt to bring greater objectivity into the system of product development. Some examples of these techniques are:

Idea generation by systematic methods
Market evaluation based on Bayesian decision tree methods or cost benefit analysis
Formulation based on linear programming methods
Business analysis including market forecasts, market surveys and buyer simulation models.

The introduction of these techniques has been largely in a haphazard fashion. The Food Technology Department at Massey University has begun a research programme to develop a systematic approach to the application of quantitative techniques through all stages of product development. The design of nutritional products for consumers in developing countries is being used as the basis for this programme. An overview of the entire research programme is given in a thesis by Edwardson (41).

Edwardson provided an objective procedure for the selection of raw materials to be used in low cost nutritional products for the Philippines. The major problem encountered by Edwardson was the incompatibility of raw materials selected by linear programming based on nutritional criteria. It was only possible to produce an acceptable product from these raw materials through extensive processing and addition of flavouring ingredients.

It was the object of this thesis to both complement and extend Edwardson's work with the application of the linear programming model to the selection of raw materials for the production of low cost food dishes

which would meet the nutritional needs of people in Thailand. Emphasis was placed on the extension of Edwardson's model to include consumer acceptance criteria. A procedure was devised whereby raw material selection was made on the basis of their predicted acceptability in Thai food dishes.

Thailand was chosen as the environment for the study in preference to the Philippines because a cooperative programme had recently begun between the Department of Chemical Technology at Chulalongkorn University in Bangkok and the Food Technology Department at Massey University. Information on Thailand was therefore more readily available.

Thailand has a reasonable supply of food raw materials and even exports rice and sugar, but problems of malnutrition still exist, particularly in the North and North-east regions of the country. There is a definite need for the locally grown raw materials to be put to the best use through their optimum combination in acceptable food dishes. In this thesis, considerable emphasis was placed on the selection and use of indigenous raw materials.

Supplementation of local materials with imported foods has played an important role in the design of nutritional food products. Included among the most commonly used supplements are dairy products. The use of some dairy products as ingredients in local Thai dishes was evaluated both as complements to indigenous raw materials in the supply of essential nutrients and on their general acceptability in these dishes.

This thesis first reviews the availability of foods in Thailand and then suggests how the linear programming model could be used to design nutritional foods. The nutritional compositional data for a wide variety of indigenous raw materials and imported dairy products were collected, and the per capita daily requirements of the different nutrients in Thailand were found. Using this information in the linear programming

model, raw material mixes were selected to meet the nutritional needs of the general Thai population.

Goal programming, which is basically an extension of linear programming, was applied in the selection of raw material mixes to give nutritionally balanced diets. This technique was also used to evaluate dairy products as complements to indigenous raw materials in providing firstly an ideal balance of essential amino acids and secondly a balance of all 26 nutrients which were considered in the model.

A procedure for raw material selection based on their acceptability in combination in food dishes was obviously required in the linear programming model. A review of the literature relating to sensory evaluation and consumer acceptance of foods failed to provide any procedure which might be used directly. The problems of definition and measurement of the raw material properties which influence the acceptability of food dishes directed the research toward a study of multivariate techniques. Nonmetric multidimensional scaling was identified as a technique which could not only resolve the properties but could also provide metric scale values for these properties which might be used directly in the linear programming model.

A subset of the original list of raw materials was selected. Proximities data on these raw materials were obtained from consumer surveys in Thailand and were subjected to multidimensional scaling analysis. A 3 dimensional spatial configuration of the raw materials was derived and the axes of this space were identified as the dominant properties of the raw materials in determining their acceptability in Thai food dishes. A linear function was derived relating these raw material properties to the acceptability of food dishes in which the raw materials are used. The function was included in the linear programming model together with nutritional constraints to provide a quantitative model for the selection of raw material mixes for nutritious and acceptable Thai food dishes.