CHAPTER 5

Product Design and Process Development

5.1 Introduction

Product design takes a long time and a great deal of effort. It is important to target the design programme to minimise time and costs and to plan for it to be successfully completed within allocated resources. Time is very much of the essence, the minimum compatible with optimal development.

In a product design plan, there are many activities to be first recognised and then coordinated; some activities are worked in sequence, some in parallel. In particular, multidisciplinary activities are focused in the same direction and coordinated in time. The master plan coordinates the various people and their mini-projects in an overall time and resource plan so that the product design can be controlled.

The plan begins with the product design specifications. These include a profile of the product characteristics as defined by the consumer, the structure and composition, safety factors, convenience and aesthetics, and also indicates the manufacturing, processing and storage variables and their effects on the product qualities. Many of these product design specifications start as general descriptions; product design and process development focuses them into definite, quantitative descriptions.

In the design process, the product and process development are integrated so that at the end of the design stage there is a product with the optimum qualities, and a process to produce it. A great deal of time is lost if a food product is designed under 'kitchen conditions' and then has to be redesigned as the process is developed.

In food product design:

- **important marketing factors** are consumer acceptability, competitive positioning, legal regulations, ethical requirements, environmental mandates and distributor requirements;
- **important technical factors** are raw material availability, ease of processing, cost, attainability and reliability of product quality, shelf life, equipment needs, human knowledge and skills; and
- **important financial factors** are costs of manufacturing and distribution, costs of further development and the investment needed.

These are considered at various parts of the design so that at the end of the product design and process development they can all be included in the feasibility report for top management.

5.2 The design process

The design activities are grouped into steps: 'getting the feel', screening, ball-park studies, optimisation and scale-up of production and marketing, leading at the end to product and process specifications, marketing strategy and financial analysis as shown in Figure 5.1. This allows control of the design process as the consumer, product and process activities are coordinated into small mini-projects with specific objectives.

The activities and some of the experimental techniques in the various stages of product design and process development are shown in Figure 5.1. The stages used in this book are ‘getting the feel’, screening, ball-park studies, optimisation, scale-up (production) and scale-up (marketing).

Figure 5.1 Activities and experimental techniques in product design and process development

PRODUCT DESIGN SPECIFICATIONS

↓

'Getting the feel'	Recognising the variables Setting the limits *'Ad hoc' experiments*

↓

PRODUCT 'MOCK-UPS'

Screening	Importance of variables Interrelationships of variables *Simple experimental designs*

↓

ELEMENTARY PRODUCT PROTOTYPES

Ball-park studies	Variables limits Variables interactions Basic packaging *Linear programming* *Factorial designs*

↓

ACCEPTABLE PRODUCT PROTOTYPES

Optimisation	Stepwise variable changes in small area Aesthetic product design Complete process design *Optimisation designs*

↓

OPTIMUM PRODUCT PROTOTYPE

Scale-up: production	Process testing in plant Yields study *EVOP* *HACCP*
Scale-up: marketing	Marketing/product definition Market channel selection Pricing analysis Sales prediction *Consumer panels, large consumer test* *Market survey* *Sales forecasting*

↓

FINAL PRODUCT PROTOTYPE
PRODUCT AND PROCESS SPECIFICATIONS
MARKETING STRATEGY FINANCIAL ANALYSIS

FEASIBILITY REPORT

In the design, both the input variables to the process and the output variables of the product qualities are identified early in the developments.

The input variables are:

- raw materials: type, quality, quantity;
- processing variables: types of processing, processing conditions.

The output variables are:

- product qualities;
- product yields

The levels of the input variables that are possible in the production are identified and used in the design experimentation. The level of a raw material (or ingredient) is the percentage in the formulation. Raw materials and ingredients are sometimes differentiated: raw materials as the primary products from agricultural and marine sources, and ingredients as processed materials. In this book, raw materials includes both, and mean all materials used in the process. The levels of processing variables are related to physical, chemical and microbiological measurements and also the achievable and necessary limits set by equipment and environmental conditions. There are limits set on the input variables by the needs of the product, processing and costs; there may be a lower level and a higher level, or just one of these. Identifying these levels early in the design reduces the time spent on experimentation.

The product qualities wanted by the consumer are identified and quantified. Usually a range is discovered within which the product is acceptable; this sets the range within which the quality has to be controlled. Again there are usually low and high levels identified for the product qualities. The yield of product necessary to give acceptable costs is identified early in the design to direct the raw material and process experimentation.

The design is a continuous study of the relationships between the input variables and the product qualities, so that the final product prototype is the optimum product under the conditions of the process. The two main parts of product design are making and testing the product prototypes, and the two important groups of people are the designers (often called developers in the food industry) and the consumers. The prototype products are tested under the standards set by the product design specifications, so that product testing needs to be organised along with the product design and the processing experiments. Regularly there is consumer input, to confirm that the product is developing characteristics as identified in the product concept and not developing characteristics which are neither wanted nor needed by the consumer.

As discussed in Chapter 1, the product design ends with a final product prototype and a feasibility report:

- defining the feasibility of the product for technical production, the market and the company;
- anticipating the technical and market success;
- assessing the financial feasibility; and
- predicting associated impacts on the company and the market of various levels of product success.

Gathering information for the feasibility report is an important part of the design process.

5.3 Steps in product design and process development

Carrying out the design in the five successive steps listed in Figure 5.1 goes some way towards eliminating the mistakes of choosing the wrong design and also making the product on a large scale when very little is known of the processing system.

5.3.1 'Getting the feel'

This is a continuation of the development of the product concept and the product design specifications. The processing methods and conditions outlined in the product design specifications are used to make the early product prototypes, and the technical testing methods are examined for reliability and accuracy in testing both the technical product characteristics and also their relationships to the consumer product characteristics. There is a question of consumer involvement at this stage; some people advocate this strongly because it means that there is control over the design; others say that it is faster and just as accurate to use the knowledge of the designers. The choice of no consumer testing depends on the level of consumer knowledge held by the designer. The basic costing used in the company is also identified so that a simple method of determining costs can be used in the next stages of the product design. The target market was identified in the product concept stage and the consumers are selected to represent this target market(s).

5.3.2 Screening

Screening reduces the wide range of raw material and processing variables to the input variables affecting important product qualities. This hastens the design. Initially the variables can be reduced using the previous knowledge of the designer and also published or company information easily available. There can still be a number of floating variables and these are studied in controlled experimentation, not 'ad hoc' try-and-see experimentation. Many experimental designs are available to screen the variables but the most common are partial factorial designs, or Plackett and Burman designs. In a Plackett and Burman design, it is possible to screen N-1 variables with N experiments. The screening experiments identify the important variables and their magnitude levels that affect the product qualities, but they are not statistically accurate and cannot quantify the relationships between the input variables and the product qualities. Some food designers have the consumers test many samples in these designs, sometimes for acceptability, but more usefully in product profile tests. Other designers use trained sensory panels.

At this stage, the raw materials are being selected, and the quality, availability and costs of those raw materials are studied. There is likely a basic total cost range for the raw materials, but it is important not to select individual materials only on cost at this stage. Higher qualities of raw materials may give a unique property to the product, and also the more expensive materials may not need to be used in the same quantities as the cheaper. Sometimes there are restrictions in the company on the raw materials that are to be used; the buying department can often give some indications without restricting the design.

5.3.3 Ball-park studies

In ball-park studies, the aim is to set the limits of the raw materials and the processing variables which give acceptable product qualities as judged by the consumer. By this stage, the variables are reduced in number and their outside limits are set. They are examined in factorial designs, and for raw materials in mixture designs. In factorial designs each input variable is considered at high and low levels, and the combinations of these high and low levels for all input variables are tested. In a full design all possible combinations are run, therefore for three variables the total number is $2^3 = 8$ experiments. In food formulations, mixture designs are often used because it is impossible to vary one ingredient while holding all the others constant; in mixture designs, the sum of all the ingredients in the formulation must add to 100%. The product designer must always be aware that when they change the content of one ingredient, the proportion of the other ingredients changes, for example reducing the fat content will increase the proportion of other ingredients: carbohydrate, protein or water. With factorial designs and mixture designs, the effects of the various input variables, alone and together, on the product qualities are analysed, and mathematical relationships developed between the input variables and the product qualities. To set up the experimentation and to analyse the results, there is computer software readily available for food product development.

Both technical testing and consumer testing of these product prototypes are carried out. The consumers are testing for acceptability and the technical tests are examining the chemical, microbiological, physical and sometimes the sensory properties of the products. Accuracy and reliability are important considerations in this testing, both for studying the effects of the input variables on the product qualities and for developing the quality assurance programme. The total processing costs of these product prototypes are compared to identify the effects of the input variables on the costs, and to check that the costs are within the target cost range.

Think Break 5.1

Steps in product design and process development: consumer testing

Discuss the advantages and disadvantages of consumers testing the prototypes in 'Getting the feel', 'Screening' and 'Ball-park' experimentation.

For what types of products – packaging change, product improvement, product line extension, product innovation – would you use consumer testing and at what stages in the product and process development?

5.3.4 Optimisation

Here the aim is to optimise the overall product quality by determining the levels of the input variables which will give the best possible product quality. The problem is that often when optimising one product quality, another product quality is less than optimum. So it is a case of setting the relative importance of product qualities, and for the most important product qualities studying the formulation and processing variables to find the optimum. But the limits that are acceptable across all the product qualities need to be known so that during the optimising experiments none of the other product qualities become unacceptable. . For raw material formulations, linear programming can be used to optimise a number of product qualities and costs with the amounts of raw materials in the formulation held between upper and lower levels.

5.3.5 Scale-up

Scale-up (or ramp-up) of both the production and the marketing is the last stage of the product design and process development. The production scale-up is the in-plant test to verify that the product can be made at the quality and quantity required, and the marketing scale-up is a large consumer test to verify that the target consumers will buy the product and what marketing strategy will encourage this buying.

The aim of the processing scale-up is to determine the optimum production process for product quality, product yield, process control and costs. If the previous design research has combined the product and the process, this can be achieved without too many problems. But if the process has been ignored, then there can be disastrous problems. For example, if some of the intermediate materials have never been pumped during the design experimentation, then they could break down during scale-up.

The scale-up can be either on a pilot plant or short production runs on the main plant. If it is a new process, or there is to be quite extensive experimentation, then the scale-up is conducted on a pilot or small-scale plant. If the process is only an adaptation of the present production, then the scale-up is conducted on the main production plant. The decisions on the type of scale-up are often much influenced by cost; the production trial can cost a great deal if the product cannot be sold and this restricts the use of the production plant until the final stage. But if there is no investment money to build a pilot plant then the production run may be the only scale-up available. The question can often be asked as to when the scale-up from the laboratory bench to the small plant to the production line should be carried out. A great deal of time can be spent perfecting a product in the laboratory, only to find that it is impossible to duplicate this in the plant. If the product is rushed from the laboratory to the production line, then there can be a great deal of raw material and product discarded at a substantial cost.

Knowledge of the interrelationship of the processing variables and the product qualities can reduce these failures. EVOP (evolutionary operations) are used in optimising the process variables, especially if using the production line in scale-up. EVOP is a way of plant operation that tests small changes in the process variables in a simple factorial design. It continuously changes the process variables until optimum product qualities are reached, but only slowly so that the product can be used for large scale testing or even sold.

The marketing scale-up aims to define the market, describe the market strategy to reach this market and predict the possible sales revenues for the product. Possible market channels are studied and the market channel suitable for reaching the target consumers and for the company is chosen. The price range related to the production costs, competitors' pricing and company policy is tested with consumers to see how it affects their buying intentions. Also the final product concept (the product proposition) is built up from the final prototype product, the packaging design and consumer studies. The definitions of the product, price and market channel are used not only to develop the aims and methods for the promotion of the product but are also the basis for planning the marketing mix during product commercialisation.

The final prototype product from the production scale-up and the various parts of the marketing strategy are tested in a large-scale consumer test where the consumers test the product in their usual environment and are interviewed about the marketing strategy.

Think Break 5.2

Activities in product design and process development: rice risotto

The company has decided to produce a rice risotto, a dry flavoured mix to which only boiling water is added to give a quick snack, similar in use to instant noodles. Identify some of the important activities in the design of this product.

In Case Study 5 are some comments on food design for the future from an Italian design journal, to start you thinking about the development of food design. Certainly today there is a need to determine the direction of food design both for food ingredients and consumer products, and also for the fresh products which are being designed on the land and in the water.

Case Study 5.

Towards a Food Design

The food product development project passes from a traditional approach aiming at the adjustment of natural food, to an approach based on consumer needs, and then to an approach implying the interpretation of food technology potentialities in the framework of the food culture of eaters. Food design aims at closing the gap between what is culturally acceptable as nourishment and the extreme technological situation of foods consisting of the most artificial nutriments.

It must combine artificiality with quality by integrating into the food development project all aesthetic, sensory and symbolic dimensions, along with what has been handed down and the future developments of custom and food culture, to develop 'edible objects' detached from natural products but offering the same degree of quality and richness.

Besides, it must ensure - between those who eat and make food - a mediation, not just a formal one or based on a naturalistic food, but a deeper one, asserting the technological identity of food by seeking, in the ancestral food culture as in the chaos of present day behaviour, a poetical spirit that may make it more valuable.

(From François Jégou (1996) 'Design and food; object-food and food raw materials', *Stileindustria*, 2(6), June, pp. 40-1.)

5.4 Product testing

Product testing is an integral part of the product design and process development as can be seen in Figure 5.2.

Figure 5.2 Testing activities & techniques in product design and process development

PRODUCT DESIGN SPECIFICATIONS

↓

	Technical	**Consumer**	**Costs**
'Getting the feel'	Setting up Reliability Training	Ideal profiles	Company costs
	Standard tests	*Profile tests*	*Cost analysis*
	Correlation of technical/consumer tests		

↓

PRODUCT 'MOCK-UPS'

Screening	Technical Sensory	Product comparison	Raw materials cost limits
	Product testing	*Difference testing*	*Materials cost comparison*

↓

ELEMENTARY PRODUCT PROTOTYPES

Ball-park studies	Technical Sensory	Acceptability	Preliminary product costing
	Statistical testing	*Preference panel*	*Spread sheets*

↓

ACCEPTABLE PRODUCT PROTOTYPES

Optimisation	Technical Sensory Storage	Product Improvement	Product, packaging, process costing
	Control testing *Shelf life tests*	*Use tests* *Competitive comparison*	*Cost comparison*

↓

OPTIMUM PRODUCT PROTOTYPE

Scale-up	Quality assurance	Buying predictions Marketing study	Yields Materials Equipment
	Raw material testing	*Market survey*	*Equipment comparison*
	Process study *Product study*	*Attitude panel* *Large consumer test*	*Total costing: capital and operational*

↓

FINAL PRODUCT PROTOTYPE

PRODUCT AND PROCESS SPECIFICATIONS

MARKETING STRATEGY FINANCIAL ANALYSIS

FEASIBILITY REPORT

To achieve the final product prototype, it is very important that the product is tested at all stages during its design for technical compliance, acceptability to the consumer, and compliance with cost constraints as shown in Figure 5.2***. Example 5.1*** lists the types of tests used in the development of a Thai fermented sausage

Example 5.1 Testing of Thai Fermented Sausage (Nham)

In Thai sausage product design experimentation, there were:

- chemical tests (pH, total acidity, volatile acidity, residual nitrite, reducing sugars and cooked rice),
- physical tests (Instron compression, shear force and energy, reflective colour, gas formation, water activity, weight loss),
- microbiological tests (mesophilic aerobic micro-organisms, *Enterobacteriaceae, Staphylococcus aureus,* yeasts and moulds),
- sensory tests (appearance, texture, flavour) and tests of consumer acceptability. The product profile characteristics were: colour, visual texture, air pockets, firmness, juiciness, smoothness, sourness, saltiness, spiciness, pork flavour.

Wiriyacharee, P.,(1990) *The systematic development of a controlled fermentation process for Nham, a Thai semi-dry sausage,* Ph.D. thesis, Massey University, New Zealand

5.4.1 Technical testing

Technical testing varies a great deal depending on the type of product, the testing facilities available, safety needs, processing needs and legal regulations. The tests can be chemical, physical or/and microbiological. The technical testing for consumer acceptance is built up from the consumers' product profile, and suitable technical test methods are sought which relate to the product characteristics identified as important to the consumer. In the early stages of product design, correlating the technical tests on the product qualities with the consumer product profile is essential. Technical testing is also required to confirm that any food regulations are being met, that consumer safety is ensured and that any labelling requirements for example nutritional value are confirmed. At the later stages, technical testing is developed to monitor the product specifications for quality assurance, and account needs to be taken of the accuracy and reliability of the results. Consideration also needs to be given to the costs of testing – Can the efficiency be improved? How much testing is needed for control of the product quality?

5.4.2 Shelf life testing

Testing shelf life is important in food design because there is usually a target shelf life to be achieved for transport and storage in the distribution chain as well for storage of the product by the consumer after buying. From previous knowledge, some predictions can be made early in the design on the possible shelf life; foods can be divided into short-life products (up to 10-14 days), medium-life products (up to eight weeks) and longer-life products (up to 1-2 years). The possible deterioration reactions in the food are identified, for example chemical reactions like browning and loss of colour, and microbial growth of food spoilage organisms, moulds and yeasts. It may be necessary to carry out accelerated tests under severe conditions to identify exactly what the deteriorative reactions are.

Shelf life testing needs to be started as soon as possible in the prototype development, usually at the start of optimisation experiments. Shelf life testing takes time and can be the critical activity controlling the completion of the project. The variables need to be identified - usually temperature, humidity and surrounding atmosphere in storage; vibration, handling and contamination in transport. Factorial designs are again used so that the quantitative effects of changes in the storage and transport conditions on product quality can be measured.

Think Break 5.3

Product testing: shelf life

The 'use by' or 'best by' dates on food products are indicative of the shelf life of foods. The shelf life is the length of time before the consumer can recognise a change in quality or the product becomes unsafe. Look at some 'best by' dates in the chilled cabinets of the supermarkets and note the 'best by' dates for different types of foods and brands. Did the information on the package include storage temperatures?

How would you use this information for setting the conditions for shelf life testing of two new products: (1) natural active yoghurt (2) vacuum packed sliced salami?

(See Lewis, H. And Dale, R.H.(2000) ‘’Chilled yoghurt and other dairy desserts’ in Man, C. M. D. and Jones, A. A. (eds,), *Shelf-Life Evaluation of Foods,*2nd. Edition, Gaithersburg, Maryland: Aspen Publishers pp.89-109.)

5.4.3 Sensory evaluation

Sensory evaluation can be carried out by expert sensory panels or by consumers. Traditionally in product design, the expert panel determined the differences between prototypes and the direction of the differences, while consumer panels evaluated the acceptance of products or preferences between products. This meant that consumer input did not take place until the final stages of prototype development. But with the acknowledged importance of the early stages of product design, consumer panels are now used to guide the design. Such panels are used in screening the ingredients, determining the product characteristics and their strength in the ideal product, developing and optimising the product profile of the product prototypes, and optimising products for acceptance and cost. Care needs to be taken when choosing the “consumers” – are they the people who buy the product, who prepare the meal, who eat it?

A trained panel may consist of between four and ten people, but consumer panels are larger, comprising at least thirty people depending on the type of testing. The members of a trained panel after a month or longer training are able to score the product qualities reliably and accurately. Consumer panels are not trained, but are representative of the users of the product. Initially consumer panels were considered 'too much work' and expensive, but experience has shown that this is not so.

The size of the consumer panel increases throughout the design as the importance of making the right decision becomes critical and the penalty for a wrong decision becomes larger. In product formulation, it can consist of 15-20 consumers, rising to 50-100 consumers during the final processing trials and 200-300 for the final product prototype, while in some large markets with greater variability it may be even more. The smaller panels are useful when some depth of knowledge is needed though they are not a statistically valid method of determining how many people in the market will buy the product. But over the years, it has been shown that there are significant correlations between the verdicts of the consumer panel and the larger consumer test if the members of the consumer panel have been selected carefully and are representative of the market.

Consumer panels are used for seeking in-depth information about the product's characteristics and uses. The aim is to obtain as much detailed information as possible so that informed changes can be made in the product design. The consumer panel gives opinions on all product characteristics, not just sensory qualities but others such as safety, nutrition, size, ease of use, transport, storing and convenience. They can also be involved in the design of the package. The final consumer panels test the packaged product under the conditions in which they would use it. This would normally be in their home, but sometimes because of secrecy and also the need to watch their use of the product such trials may take place in the laboratory. For example, there is a need to check: Is the pack ergonomically suitable? Does it fit their hands? Can they open it? Is the product suitable for their equipment and their abilities? Can they prepare and cook the product? Do the other people in the house like it? Is it acceptable to younger/older people, different sexes?

Think Break 5.4

Product consumer testing: dog food

A company is developing a dog food for the working dogs in the rural market. The product is a large sausage which can be stored at ambient temperatures. It is, with dog biscuits, the dogs' only food.

Outline the consumer test programme that you would organise with the dogs and their owners from the start of the product design to the final selection of the product prototype at the end of the product design.

5.4.4 Costs

Costs provide a basic criterion for controlling the design; they need to be monitored throughout development to ensure they are within the target range. At the beginning of the design, the company's cost structure and the target range of costs for the new product need to be agreed by all involved. The basic costs for producing and distributing the product can be subdivided into manufacturing costs, distribution and marketing costs and general company costs. A simple breakdown is shown in Table 5.1

Table 5.1 Basic costs for producing and distributing a product

Manufacturing costs	Raw materials cost Direct processing costs Fixed costs Plant overhead costs
Distribution and marketing costs	Physical distribution costs Market channel costs Promotion costs Sales and selling costs
General company costs	Administration costs Development costs Financing costs

Some of the manufacturing costs comprise raw materials, packaging, labour, depreciation of equipment, electricity, steam, gas, water, waste disposal and plant overheads. In many companies, during the product design and process development, the raw materials and direct processing costs are continuously determined and are part of the design. For example, in the linear programming models for product formulation there is usually either a total cost constraint for the raw materials or the aim is to minimise cost. Standard percentages or ratios on these materials and processing costs are used to predict the company costs. This has to be carried out with care, especially with innovative products or new markets where some of the marketing and distribution costs are unknown - these may be found to be too high only at the later stages of the project and prevent the launch. At the end of the product design and process development stage, there should be reasonably accurate forecasts of production and distribution costs and some indication of the probable marketing costs.

Think Break 5.5
Product testing: fruit drink powder development

Fruit drink powders are dissolved in water to give a refreshing drink. These drinks are popular with children, and are also used as cheap drinks for large parties.

1.Identify the ingredients in fruit drink powders by reading the labels on some powders available in the supermarket or by searching in the internet e.g. 'Ingredient manufacturers turn powder into health gold' by David Feder.
http://www.foodprocessing.com/articles/2008/370.html Sighted 14/11.2008.

2. Identify the important product qualities in such powdered drinks, and suggest how you might test these product qualities with laboratory testing, with trained sensory panel testing and with consumers.

3. Fruit drink powders are produced by mixing the ingredients so that they are evenly dispersed and then they are packed into sachets. Identify important factors in this processing and packing.

Outline the method you would use to develop a fruit drink powder, combining Figures 5.1 and 5.2 in one diagram.

There are three important general activities in product design: product formulation, packaging development and processing development.

5.5 Product formulation

Many food products are made by combining raw materials in specific proportions in a formulation, and research on the effects of various formulations on product qualities is common in product design.

In systematic formulation there are five steps:

- Set the product qualities required,
- Find data for the raw material compositions, qualities and costs,

- Determine limits on the raw materials and the processing variables,
- Use quantitative techniques: linear programming, experimental designs, mixture designs,*
- Use product profile tests and technical tests to relate product qualities to changes in formulations.

(*there are many useful computer software packages to use these statistical techniques.)

The raw materials can be divided into two groups: the basic product raw materials and the 'top' or aesthetic raw materials. This does not mean that the basic raw materials do not give aesthetic qualities to the product - in fact in modern food design this is recognised as a fundamental factor. But sometimes there is a need for the addition of colours and flavours to improve the aesthetic effect. The important properties of the raw materials in relation to the product qualities are recognised in the product design, as shown in Example 5.2.

Example 5.2 Raw materials for Thai Fermented Sausage (Nham)

1. Meat System: fresh lean pork and pork-skin, held at ambient Thai temperatures for three hours after killing.
2. Curing agents: sodium chloride, sodium nitrate, sodium tripolyphosphate.
3. Seasonings: white pepper, fresh garlic.
4. Carbon sources for fermentation: jasmine rice (cooked), glucose.
5. Starter cultures: *Lactobacillus plantarium, Lactobaccillus brevis, Pediococcus cerevisiae, Micrococcus varians.*
6. Sausage casings: cylindrical tubes, 22.5 mm diameter, 30 cm long, made from laminated 15 micron uncoated nylon and 50 micron linear low density polyethylene.

Limits on raw materials

Meat system was set at 80% ground meat 20% sliced pork skin.
The low and high levels for the other ingredients and starter cultures were:

Raw materials	% *meat* system	Starter Cultures	cfu/g *meat system*
sodium chloride	l ,4	*Lactobacillus plantarium*	0, 10^6
sodium nitrate	0.01, 0.03	*Lacobacillus brevis*	0, 10^6
sodium tripolyphosphate	0, 0.5	*Pediococcus cerevisiae*	0, 10^6
minced garlic	3, 7	*Micrococcus varians*	0, 10^6
white pepper	0, 0.05		
cooked rice	5, 8		

Screening experiments

A Plackett and Burnam experimental design was used to screen these raw materials. From this, the important raw materials affecting the qualities of the Nham were identified as the four starter cultures and the rice, and in further experiments these were studied at different levels and under different processing conditions. Glucose as another carbon source was also studied. The other ingredients were fixed: sodium chloride 3%, sodium nitrate 0.02%, sodium tripolyphosphate 0.3%, garlic 7.0%, white pepper 0.05%.

Wiriyacharee, P.,(1990) *The systematic development of a controlled fermentation process for Nham, a Thai semi-dry sausage*, Ph.D. thesis, Massey University, New Zealand

In formulation studies, the important development in the last ten years has been the use of the computer. First, there is the raw material database on the computer; this started by detailing the chemical and nutritional compositions of different raw materials but has expanded to other properties such as microbiological quality, sensory qualities and to the effects of raw materials in processing, where this information is available. For companies with a narrow range of products, this raw materials database can be used in all product development projects as a starting point for formulation; in other companies with a wide-ranging product mix there may be need for two or three databases. The database is only useful if it is kept up-to-date and is also related to the company's buying policy.

The database can be used to build and analyse various formulations to see how they fit the criteria for the product qualities, the costs and the processing. This can be done quite simply using computer spreadsheets. There are also expert systems available which provide a decision support framework made up of two parts: a task part containing the distinct problem-solving steps involved in creating a formulation, and a physical part with the specific knowledge about the properties of the raw materials and the processes involved. As more information is obtained from factorial experimentation, mathematical relationships between the raw materials in the formulation and the product qualities are developed and these can be used in such techniques as linear programming.

Think Break 5.6

Product formulation: natural fruit ice-cream

For developing a formulation for natural fruit ice-cream, identify the important raw material variables and the important product qualities.
Relate each raw material to a product quality(ies); for example, lecithin, an emulsifying agent, stabilises the oil/water emulsion and gives smoothness to the ice-cream.
See: *The Science of Ice Cream* by Chris Clarke, 2004 Published by the Royal Society of Chemistry.

5.6 Packaging development

Packaging design at this stage concentrates on the packaging of the individual product; the outer packaging research is only related to decisions regarding size and to the protection required during distribution. The design of the packaging for the individual product is based on the needs of the consumer and the requirements of product preservation and protection in the product design specifications, but it also considers the process and the distribution, as well as the needs of retailers and the environment.

The graphic design is usually carried out during the commercialisation stage together with the promotional artwork, but consideration needs to be given to any printing and display needs in the selection of the packaging and the materials to be used.

The needs of the consumer and the retailer dictate the dimensions as the package has to be stored on retailers' and consumers' shelves, consumers have to be able to handle and open the package with their hands, the quantities are related to the serving of the food and the packaging has to stand up to the general conditions of use. The packages have also to fit into the standard outer container shapes and sizes.
The product may be processed in the package in which case the package must be able to stand up to the processing conditions and also not interact with the food during processing and storage, for example packaging constituents leaching into the food. In all cases, the package needs to fit into the packing line with not too much adaptation.

The factors to consider in packaging design at this stage of product and process development are summarised in Table 5.2.

Table 5.2 Factors in packaging design

Consumer	Buying, transporting, storing, using, eating, disposing
Product	Containment Protection in external environment, distribution Presentation for communication, promotion, selling Use by consumer: convenient, dispensable, ergonomic, information Legal requirements
Process	Preservation of food, processing ability, interaction with processing, Product packaging quality Machine ability in making, forming, filling, closing
Distribution	Outer packing, unitisation, transport, storage conditions Retailer needs Storage, display, communication, bar coding, tamper-proofing
Environment	Resources used: energy, raw materials Waste: reuse, recycle, or disposable

From the research, the packaging is defined as packaging material (films, cardboard, metal, glass, solid plastic), packaging type (bottle, carton, pottle, can), packaging size, packaging method (hand, continuous, automatic, aseptic). The designer does not have a great deal of room for originality in food packaging except with regard to the graphic design, but there is still a great deal of originality as can be seen on the supermarket shelves. The use of computers with design software has made it easier to design packaging.

The package is then put to the test on the processing/filling line, and for shelf life, and product protection during storage and transport. Finally the consumer has to test the packaging with the product.

5.7 Process development

Process development is interwoven with product design. For example, in the Thai sausage example a standard fermentation process was chosen for the Plackett and Burnam experiments, and then in the later studies on the starter cultures, the processing variables of temperature and humidity were also studied during fermentation. The Thai sausage processing was divided into three parts: raw material preparation (mincing of meat, cooking of rice), mixing of the raw materials and stuffing into the sausage casings, and fermentation. The first two parts were kept standard throughout and only the fermentation conditions were varied.

This division of the process into its individual parts is the method used in either analysing a current process for a new product (process analysis) or for building a new process for a new product (process synthesis). The individual parts and then the connections between them are studied to give the optimal overall process. There are three aspects of studying processing: unit operations, unit processes and processing limits:

- ***Unit operations.*** These are the physical processes such as heating, pasteurisation, sterilisation, freezing, chilling, drying, mixing, emulsifying, tumbling, pumping, conveying, packing. They can be grouped into separation processes, assembly (or combining) processes, conversion processes and preservation processes. There are more than a hundred unit operations used in food processing.

- ***Unit processes.*** These are the chemical, biological and microbiological changes such as gelatinisation, hydrolysis, oxidation, browning, protein denaturation, vitamin destruction, destruction and growth of micro-organisms, fruit ripening and meat tenderising. There are a number of these reactions occurring together in a food process and this leads to a complicated study in design. In the past much of the knowledge was empirical, but gradually basic quantitative studies of the rates of these reactions are leading to more directed process design.
- ***Processing limits*** (maximum and minimum). These can be temperatures, rates of increase/decrease in temperature, viscosities, mixing speeds, shear rates and pH, as well as processing times, availability and cost of equipment and services such as water quantity and steam pressures.

The combination of basic knowledge of food processing which has been built up over the last twenty years and the use of computers has led to a great deal of change in food product design and process development from the recipe testing of the past to systematic design based on process engineering principles and knowledge of food chemistry, biochemistry and microbiology.

The development steps are common in all projects, but the relative amounts of time and effort required for different steps may change considerably. Many food products are processed in more or less generic equipment so the emphasis in development lies on the product. If process development is more extensive, the logical sequence remains but the description of the steps may change, for example detailed design for items of equipment or a continuous line are included.

Think Break 5.7
Process development: allocation of time and effort for different products

Consider the relative time and effort which you would need to allocate to the various steps set out in Figures 5.1 and 5.2 when developing each of the following products:

- the risotto product (see Think Break 5.2, Section 5.3.5);
- the fruit drink powder mix (see Think Break 5.5, Section 5.4.4);
- a new frozen bar in which a soft caramel centre is surrounded with fruit ice-cream and enrobed in chocolate (see Think Break 5.6, Section 5.5 for fruit ice-cream).

5.8 Building the marketing

Consumer panels can be used during the product design to devise the best method of marketing the product; such panels build up knowledge of their relationship with the product, the acceptable price range and the product image. Distribution testing of the prototypes builds up knowledge about the physical distribution system and the market channel possibilities. Costing analysis gives an idea of the basic product and marketing costs. The marketing researchers then have a great deal of knowledge on which to build the marketing strategy.

The researchers are then able to determine:

- price range,
- relationship of the product to competitive products,
- product's position in the market,
- various market channels and their suitability for the product,
- target market segments and
- product image.

Having done this, they test the product in a large consumer test so that they can confirm the marketing method and also determine sales potential and market share.

5.8.1 Market survey

Market survey combines a number of activities whose objectives are to select the market segment(s) and the position of the product in the market segment, to determine the possible sales to the market segments, and to find information on which to base the marketing strategy. The information from the consumer research in the product design needs to be confirmed and expanded, either by secondary market research using published information and company information, or by primary market research using consumer focus groups, retail audits, and studies of the competitors and of the industry.

Focus groups may be organised to collect in-depth information on the target market, product, price, buying place, promotion, preference, preference over competitive products and long term buying predictions. Retail audits can be bought from commercial companies who regularly monitor sales of products in retail outlets, or more likely today, from the summarised information of supermarket electronic data. This information not only gives the market shares of the competing products, but continuous sales records, which can be a basis for sales forecasting. The sales of competing products need to be backed by information on the qualities of the different competing products, from either technical comparison or consumer comparison of the products, as well as on the competing companies and their methods of marketing. For industrial products, there is a need for industry studies to discover the different customers in the market and their characteristics - size, method of processing, company organisation, economic status, and present use of raw materials.

There is also a need to study the whole market channel and the physical distribution system. In consumer food marketing, the retailers have a strong control on the introduction of new products, so there is a need to study the competing products on their shelves and how they promote them, their attitudes to new products, and the effects on their new product behaviour of the prices, discounts, and promotional financing by the manufacturers. One also needs to investigate any retailers' charges to obtain shelf space for new products.

The place of the new product on the company's and the market's product life cycle is determined to ensure that a suitable marketing strategy is selected. Internally, the place of the new product in the company's product mix and product line is studied to see how the new product will affect the complete product mix and also individual products.

Think Break 5 .8
Building the marketing: a new starch product

A medium sized starch company has developed a new starch product which gives a clear solution with a high viscosity and a bland taste, which can be used in soups, sauces and gravies, puddings and desserts, meat and fruit pies. Discuss the types of industrial market segments that you could use for this product and how you would conduct a market survey to determine its target market segment and the position of the product as compared with other starch products.

5.8.2 Large consumer test

Large-scale product testing of the final prototype product is undertaken by consumers, or in industrial marketing by one or two large customers in their plants or by a number of food service outlets. To obtain results for the major decision to go into commercialisation, it is usually preferable to have a statistical sample of the target market so that the accuracy of the buying prediction is known. However, the sample size is often limited by practical considerations such as the amount of money available, the time to do the test and the amount of product available.

The questions to be answered in the large-scale test include:

- Which consumers like/dislike the product?
- Do they prefer it to competing products?
- What product characteristics need improvement?
- Does the product or the packaging need to be redesigned?
- Will they buy the product at the given price?
- In what price range will they buy the product?
- How much will they buy, and how often will they buy at the different prices in the price range?

The consumer products are tested in a central location such as a shopping mall or in the home. In the ***central location test,*** a stall or a caravan is set up in a central position such as a shopping mall and people passing are asked to taste the product and give their comments on a self-administered form or in an interview. This does not give a random sample of the population but it is quicker and cheaper than the in-home test. In an ***in-home test,*** the consumers are given a sample of the product, either unidentified or with the full branded pack, and asked to prepare and eat it in their household. The consumer or all the members of the household can be asked to comment on the product. A problem is the timing of the test which can influence a food product. It is preferable to do the consumer test at a time of year when the product would be expected to sell but this may not be possible. If done at a low acceptance time, this must be taken into account when analysing the results.

Industrial product testing with small processors and food service outlets is very similar to the organisation of the in-home test. Sufficient product is given to the processor to try the product in their process, and to the food service chef to develop a dish to put on their menu. A restaurant may test this dish by putting it onto the blackboard menu and watching their customers' reactions to the dish. The processors and the food service outlets are usually interviewed after the test to find how the product has been used, the problems and successes with the product, the intention to buy, the acceptable prices and predicted quantities to be bought. With larger processors, pilot plant or small production trials are organised either jointly by the supplier and the buyer or often by the buying company because of secrecy.

Products for overseas countries should be tested in that country, and international companies either have their own testing facilities in those countries or contract local market research companies to conduct the research. International product testing uses the same techniques but presents problems. First there is the problem of language - the questionnaires have to be in the language of the consumers and there may be problems in translation not only into a particular language but even into a particular dialect. Definitions of products and product characteristics may be substantially different. Scaling methods may also have to be changed. For example the 9-point hedonic scale from 'like extremely' to 'dislike extremely' may not be acceptable in a culture where expressing negative opinions is socially unacceptable so the dislike terms have to be removed.

Think Break 5.9

Building the marketing: in-home testing of a baking mix and a dairy cream

Outline how you would organise an in-home test for:

- baking mix for making muffins**;**
- dairy cream in an aerosol can.

Decide on the questions that you want answered, how you would present the products and the packs, the target consumers, the distribution of the samples and the questionnaires.

How would you use the results?

5.9 Product and process specifications and marketing strategy

Outline process plans include raw material specifications and quantities, process flow charts and processing conditions, product quality specifications, process control points and product testing methods. From this information, product and process specifications can be written and an approximate product cost determined. If necessary, legal or governmental approval is sought for the product or/and the process. An approximate idea of the customer and consumer acceptance of the products is already known; from this and historical sales data, sales forecasts can be determined. From the consumer and market studies, the marketing strategy can developed.

5.9.1 Product and process specifications

Final specifications include the raw material specifications, the product formulation, the process flow chart, the processing conditions in the individual unit operations, a preliminary HACCP analysis of the process, the testing of the intermediate and the final products, and the final product qualities. These are based on only preliminary production runs and can change during the commercialisation.

5.9.2 Costs and prices

Costs and prices are predicted from the trial production runs and from the consumer test. These will be ranges at the present time, as the production yields are only based on the small-scale tests, and the prices are only based on consumer comments, not actual buying. Usually pessimistic, most likely, optimistic, predictions are made for the costs and the prices.

5.9.3 Sales forecasts

Sales forecasts are based on the consumer test results: the target market segments, the total number of potential customers and the potential consumption rate. There will also be a proportion of potential consumers who will not buy the product and this is also known from product test results. From this type of data and allowing for direct competition, it is possible to make an estimate of the probable sales. However, this estimate must only be used in conjunction with estimates from other sources, since the details of buying intentions given by consumers to market researchers are notoriously inaccurate.

Sales forecasts for most products can be made by considering sales levels of similar products in conjunction with past and current socio-economic trends. Past records can, in general, be used in two main ways. First, a past trend can be directly extrapolated on the assumption that the causes which led to its occurrence will be maintained at the same level in the future. Second, an analysis can be made of the chief determining factors of any trends, and an attempt made to estimate future trends in accordance with any variations expected as a result of those factors.

A broader approach to sales forecasting includes the factors which have an overall effect on the economic behaviour of the nation. Most new products are in the non-staple food class; they are convenience products, impulse products, or alternative food choices, and sales levels of these can be affected by changes in total consumer expenditure. Detailed discussion of forecasting is not possible here but all the above factors will need to be considered to make reasonable forecasts. Sales forecasting is now a scientific technique which has been developed to make predictions as rational as possible, exploring every conceivable factor which could affect sales. Sales forecasts are sometimes wrong but all efforts must be made to ensure they are incorrect only for the most unexpected or unusual reasons.

5.9.4 Marketing strategy

The marketing strategy is built up, to outline and integrate the product, the packaging, the price, the distribution methods and the promotional message. At this stage, these are still general descriptions, and the two most important decisions to be made concern the objectives of the market strategy, and the product concept developed from the final product prototype and earlier research. At this stage the product concept is being developed into a **product proposition,** which is the basis for the product communications in selling and promoting the product during the commercialisation.

5.9.5 Financial analysis

This is based on the costs predicted by the processing and marketing research, and the prices and sales forecasts from the market research. From these, the future cash flows and profits are predicted. Capital investment for the production plant and maybe the distribution system are estimated, and the working capital for the commercialisation and product launch predicted. From this information can be predicted rates of return on investment and also break-even times for development costs to be recovered. At this stage, these predictions have quite a high range of inaccuracy, and risk of being wrong; therefore probabilities of accuracy are placed on the predictions

The product and process specifications, the sales forecasts, the marketing strategy and the financial analysis, although at this time not exact, give excellent information for a feasibility study and for the evaluation of the product before the very expensive step of commercialisation is attempted.

5.10 Summary

Product design and process development is a vital part of the product development project, combining product, process, market and consumer research. These multi-disciplinary activities are completely interconnected and form a highly creative part of the project. The knowledge base is very wide, although sometimes there is little depth to parts of it. At the end of product design, a factual feasibility study has to be produced from this mass of information. Therefore, product design needs to be systematically planned and controlled, while still allowing space for creative behaviour.

In the food industry in the past, this was a rather an ad-hoc, empirical procedure. With the introduction of computers and the greater basic knowledge becoming available, it is now developing into a technological process with a strong consumer base element. Consumers are an integral part of product design, and are included in the testing of the prototype products.

Three test factors in product design are consumer acceptability, technical feasibility and costs; these must be considered at all stages of the design.

Product design finishes with the first attempts at defining the product specifications and the marketing strategy which will be the basis for the commercialisation. The financial aspects of cost, price and sales potential, are predicted, as well as the investment needed for further development.

5.11 Suggested readings

Arteaga, G.E., Li-Chan, E., Vasquez, M.C. and Nakai, S. (1994) 'Systematic experimental designs for product formula optimization', *Trends in Food Science and Technology*, 5(8), 243-54.

Bruin, S. (1992) 'Integrated process design: issues and opportunities', *Transactions of the Institution of Chemical Engineers*, 70, Part C, 126-30.

Coles, R.C. and Beharrell, B. (1990) 'Packaging innovation in the food industry', *British Food Journal* 92(9), 21-32.

McFie, H. (1994) 'Computer-assisted product development', *World of Food Ingredients*, October/November, 45-9.

Rowe, R.C. and Upjohn, N.G. (1993) 'Formulation expert systems', *Chemistry and Industry*, 6, 15 March, 196-201.

Schaffner, D.J., Schroder, W.R. and Earle, M.D. (1998) *Food Marketing - an International Perspective*, New York: WCB/McGraw-Hill, pp. 310-38.

Some more recent readings

Earle, M. and Earle, R. (2000) ‘Adapting the methods of product design to the changes.’ *Building the Future on New Products*, Leatherhead, Surrey, LFRA Ltd. pp 79-94

Earle, R.L. with Earle, M.D. (2008) *Unit Operations in Food Processing*, Palmerston North, New Zealand, NZIFST(Inc) http://www.nzifst.org.nz/unitoperations/

Earle, R. And Earle M. (2008) ‘Important problems in food processing’ *Fundamentals of Food Reaction Technology* http://www.nzifst.org.nz/food reaction technology/

Moskowitz, H.(2008) ‘Consumer-driven concept development and innovation in food product development’ in MacFie, H. (ed.) *Consumer-led Food Product Development*, Cambridge, Woodhead Publishing Ltd. pp342-82

Project Break 5

You can use the product design specifications from the Project Break 4 at the end of Chapter 4 to start the product design.

In the company project, this will be your final product you selected.

Or if you have used Project 4, this would be a dried vegetable mix.

Instead of using either of these, you can use Project 5 for Delicatessen Salads.. You will need to select a product and write product design specifications for it.

Now plan the activities in product design and process development as in Figure 5.1.

PRODUCTION

- List the possible raw materials and their functions.
- Identify the limits on the raw materials from the product design specifications.
- Draw a process flow chart for the process.
- Identify the unit operations in the process.
- Select the important processing variables in the unit operations.
- Outline an experimental plan to design the process to give the desired product qualities.

MARKETING

- Identify the market channel and the distribution methods.
- What are the transport and storage conditions?
- What is the basic package design for processing needs and protection during distribution?
- What are the needs of the retailer and the consumer in the packaging?
- What are the promotional needs of the package?
- What is the price range for the product?

Now: 1. Describe the final product prototype, including the package.

2. Outline the product and process specifications.

3. Outline the marketing strategy

4. If possible, do a financial analysis

5. Finally write a two page feasibility report.

Project 5 Delicatessen Salads

A logical development for the mayonnaise-based salads industry is the production of entire mini-meals based on the salad concept. Such products are in keeping with the image of a healthy diet, and they offer the manufacturer an opportunity for added value. What has limited this progression has been the inherent difficulty in making a product that is both bland (not too acidic) and safe. The product must be bland in order to allow consumption of the quantity needed to constitute a mini-meal, and yet a mild product would not have sufficient concentration of anti-microbial acids to ensure either microbiological safety or a sufficiently long shelf life.

The important constituent that controls the microbial growth and therefore the safety of the product is the concentration of un-dissociated organic acid, usually acetic acid, remaining in the aqueous phase of the mayonnaise, but this gives an acidic taste to the salad. Buffer systems, for example acetic acid and sodium acetate, have sometimes been used which can control the acidity in the food. Fermentation of the vegetables also develops acidity, and the flavour is not usually as harsh as acetic acid. An attractive feature of many mayonnaise-based salads is the incorporation of high protein ingredients such as cheese, chicken meat, corned beef, crab meat, egg, ham, herring meat, mycoprotein, prawns and sausage. These ingredients give a less acid food; standard salads are pH 3.2-4.5, but with cheese are 4.0-4.5, fish 3.6 -4.4 and meat 4.0-5.1. There are suggestions that the protein components could confer some protection on the contaminating bacteria from the hostile environment of the dressing and therefore preservation and shelf life would be reduced.

Storage conditions that can affect the shelf life of the salads are temperature, packaging and modified atmospheres. In modified atmospheres using nitrogen and carbon dioxide, the CO_2 atmosphere can cause unattractive flavour changes.

(*Source:* Brocklehurst, T.E. (1994) 'Delicatessen salads and chilled prepared fruit and vegetable products', in Man, C. M. D. and Jones, A. A. (eds,), *Shelf Life Evaluation of Foods,* London: Blackie Academic and Professional, pp.87-126.)