FORMULATION OF DIETARY FIBER-ENRICHED
INSTANT NOODLES

PIYA-ANONG PRAIRAHONG

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Piya-anong Prairahong
Generally, the recommendation for daily dietary fiber (DF) intake is 25 g, one-third of that as soluble dietary fiber (SDF). Soybean hulls (SBH), an agricultural by-product from the soybean processing industry contain low antinutritional factor and are a good source of DF especially insoluble dietary fiber (IDF). This study aimed to develop DF-enriched instant noodles, which is one of the popular ready-to-eat foods containing low DF, using ground SBH as a source of DF. Furthermore, the ratio of IDF and SDF was adjusted to be 2 and 1, using carrageenan (CG), sodium carboxymethylcellulose (CMC) and konjac powder (KJ) as SDF sources. The developed product of an acceptable quality can be a new choice for consumers who are health-conscious.

SBH was prepared by separating contaminated matter, grinding and size separating. Particles that passed through a 100 mesh screen were selected to substitute for flour in preparing noodles. Instant noodles were prepared and condition of steaming and frying processes adjusted (steamed at 100 °C for 10 min and fried at 170 °C for 1 min 10 sec to 1 min 15 sec). The basic formulas were developed and tested for acceptability. The developed formula with 0.7% guar gum and 15% modified potato starch was used as a control, then substituted with SBH. The maximum level of SBH which could be used for substituting flour was 15%. The color of the SBH-enriched product was darker and the texture was grittier than the control. To improve the quality of SBH-enriched instant noodles, gluten was added. The overall acceptability score on a 9-point hedonic scale of SBH-enriched instant noodles was around “like slightly”. Then, CG, CMC and KJ were added in SBH-enriched instant noodle formula in order to adjust the ratio of IDF and SDF as recommended. The color of CG-SBH, CMC-SBH and KJ-SBH-enriched product were slightly lighter and the texture were less gritty than SBH-enriched product. The overall acceptability score was around “like slightly” and no significant differences were found among these formulas.

From chemical analysis, the DF-enriched instant noodles provided 20% of the Thai Recommended Daily Intake for DF or 5 g per reference amount, and could be a high fiber source. The DF content of DF-enriched product was increased (4.3 times for SBH-enriched product and 4.6 times for SDF-SBH-enriched product) accompanied by a slight decrease in energy content (4.8 times for SBH-enriched product and 6.9 times for SDF-SBH-enriched product) when compared with the control formula. The ratio of IDF and SDF of SDF-SBH-enriched instant noodles was 2 and 1 as expected. The cost of the ingredients of the DF-enriched instant noodles was higher than that of the control formula.
การศึกษาที่มีความหมายในการวิจัยโดยการทำให้ผลผลิตด้วยการรักษาที่ถูกต้อง 25 วัน ต่อวัน โดยการเปลี่ยนแปลงส่วนผสมในอาหารที่อยู่ในกระป๋องไว้เป็นเปรี้ยว 1 ใน 3 ของส่วนผสมอาหารที่ใส่ในกระป๋องไว้เปรี้ยว ผลผลิตที่ได้จากสูตรนี้มีรสชาติที่มีความเข้ม ปัจจัยที่ต้องการจะเป็นผลผลิต ผลผลิตที่ได้จากสูตรนี้มีรสชาติที่มีความเข้ม ปัจจัยที่ต้องการจะเป็นผลผลิต ผลผลิตที่ได้จากสูตรนี้มีรสชาติที่มีความเข้ม ปัจจัยที่ต้องการจะเป็นผลผลิต ผลผลิตที่ได้จากสูตรนี้มีรสชาติที่มีความเข้ม ปัจจัยที่ต้องการจะเป็นผลผลิต ผลผลิตที่ได้จากสูตรนี้มีรสชาติที่มีความเข้ม ปัจจัยที่ต้องการจะเป็นผลผลิต ผลผลิตที่ได้จากสูตรนี้มีรสชาติที่มีความเข้ม ปัจจัยที่ต้องการจะเป็นผลผลิต ผลผลิตที่ได้จากสูตรนี้มีรสชาติที่มีความเข้ม ปัจจัยที่ต้องการจะเป็นผลผลิต ผลผลิตที่ได้จากสูตรนี้มีรสชาติที่มีความเข้ม ปัจจัยที่ต้องการจะเป็นผลผลิต ผลผลิตที่ได้จากสูตรนี้มีรสชาติที่มีความเข้ม ปัจจัยที่ต้องการจะเป็นผลผลิต ผลผลิตที่ได้จากสูตรนี้มีรสชาติที่มีความเข้ม ปัจจัยที่ต้องการจะเป็นผลผลิต ผลผลิตที่ได้จากสูตรนี้มีรสชาติที่มีความเข้ม ปัจจัยที่ต้องการจะเป็นผลผลิต ผลผลิตที่ได้จากสูตรนี้มีรสชาติที่มีความเข้ม ปัจจัยที่ต้องการจะเป็นผลผลิต ผลผลิตที่ได้จากสูตรนี้มีรสชาติที่มีความเข้ม ปัจจัยที่ต้องการจะเป็นผลผลิต ผลผลิตที่ได้จากสูตรนี้มีรสชาติที่มีความเข้ม ปัจจัยที่ต้องการจะเป็นผลผลิต ผลผลิตที่ได้จากสูตรนี้มีรสชาติที่มีความเข่
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LIST OF ABBREVIATIONS

DF  dietary fiber
SDF  soluble dietary fiber
IDF  insoluble dietary fiber
TDF  total dietary fiber
SBH  soybean hulls
AACC  American Association of Cereal Chemist
AOAC  The Association of Office Analytical Chemists.
SCFAs  short chain-fatty acids
WHC  water-holding capacity
LDL  low-density lipoprotein cholesterol
HDL  high-density lipoprotein cholesterol
Thai RDI  Thai Recommended Daily Intake
CG  carrageenan
CMC  sodium carboxymethylcellulose
KJ  konjac powder
MCC  microcrystalline cellulose
RS  resistant starch
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<td>mm</td>
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<tr>
<td>min</td>
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<tr>
<td>SAPP</td>
<td>sodium acid pyrophosphate</td>
</tr>
<tr>
<td>STPP</td>
<td>sodium tripolyphosphate</td>
</tr>
<tr>
<td>°C</td>
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<td>millilitre</td>
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<td>h</td>
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<td>gumminess</td>
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CHAPTER I
INTRODUCTION

Dietary fiber (DF) is the edible parts of plants or analogous carbohydrates that are resistant to digestion and absorption in the human small intestine (1-6). The functional properties of DF depend on the types of DF, which are soluble dietary fiber (SDF) and insoluble dietary fiber (IDF) (7-14). SDF acts in the upper gut where it slows digestion and absorption effects which may be beneficial in diabetes, hyperlipidaemia, and possibly in weight control. In contrast, IDF acts more in the lower gut where it has a stool bulking effect and influences bowel functions (8, 10-11, 14). A lower DF intake is reportedly associated with several disorders of the human body such as diverticular disease, colon cancer, constipation, ishemic heart disease and other diseases of the gastrointestinal tract (15-17). The survey on DF intake in Thai population presented varying results. According to the study on the DF consumption of Thai adolescents in Bangkok by Uthang, the average intake of DF in males was only 7.32 g/day and the average intake of DF in females was only 8.88 g/day (18). While the study on the daily DF consumption of nursing students in Kaukarun Nursing College by Supingklud was 8.05 g (19). On the other hand, Chitchumroonchokchhai studied on the DF intake of Thai non-vegetarian adults. The average intake of DF was 34.5 g/day (20). Generally, adolescents and adults are recommended to eat food containing 25 to 30 g of DF daily (10, 14). Because of the different types and physiological effects of fibers, one third of total dietary fiber (TDF) is recommended as SDF in order to maximize the health benefits (14, 21).
Currently, Thai staples and side dishes are being replaced by diets containing larger proportions of fats and animal meat, and smaller proportions of vegetables and fruits. Concomitant with these trends is the selection of food that requires less time and skill to prepare. Home-made meals are rarely seen and are being replaced by ready-to-cook and ready-to-eat foods (22).

Instant noodles have become one of the food products that are consumed among people of all socioeconomic levels in both urban and rural areas of Thailand (23-25). The annual production of instant noodles is 1.9 billion packs (26). However, instant noodles, especially fried type, are sometimes classified by academician as "junk food" due to their high salt, fat and carbohydrate contents and inadequate of protein (23). In addition, it contains 2 grams of DF/100 g edible portion (27) or only 4% of the recommended level of TDF in one noodle package. Although, the label on the package suggests adding meat or egg and vegetables, however because of inconvenience, this suggestion is seldom practiced by consumers (24-25). Consequently, they sustain limited nutritive value.

Therefore, this study aims to formulate DF-enriched instant noodles in order to increase amount of DF for the health benefits. Soybean hulls (SBH) are used as a source of DF, due to the results of a previous study (28) that suggested many advantages of SBH which were in TDF; especially IDF, and low antinutritional factor. Moreover, SBH are by-product from many soybean processing industries in Thailand. A combination of IDF and SDF may provide the most value because the two types of fiber complement each other in term of health benefits (2, 10, 14, 21, 29-30). Thus, the study will adjust the ratio of IDF and SDF according to the recommendation (2:1).
SBH are used as a source of IDF while carrageenan, sodium carboxymethylcellulose (CMC), and konjac powder are used as the sources of SDF.

Objectives

General objective

To develop DF-enriched instant noodles with acceptable physical, chemical and sensory characteristics.

Specific objectives

This study aims to:

(1) To formulate DF-enriched instant noodles with acceptable characteristics by using SBH as source of DF and adjust the ratio of IDF and SDF according to the recommendation by using SBH as source of IDF while carrageenan, CMC and konjac powder as sources of SDF.

(2) To determine the physical and chemical properties of the DF-enriched instant noodles.

(3) To determine the sensory acceptability and nutritive value of the DF-enriched instant noodles.
CHAPTER II
LITERATURE REVIEW

2.1 Dietary fiber (DF)

2.1.1 Definition

It is generally believed that Hipsley in 1953 first applied the term “dietary fiber” as a shorthand term for the nondigestible constituents that make up the plant cell wall. These constituents were known to include cellulose, hemicellulose, and lignin. This term “dietary fiber” was clearly an attempt to distinguish some property or constituent of the food above and beyond what was then being measured by the crude fiber method.

Between 1972 and 1976, Trowell et al. defined that above constituents as part of the “dietary fiber hypotheses”. This term was used to describe the remnants of plant cell wall components that are resistant to hydrolysis by human alimentary enzymes. The 1976 definition was primarily a physiological definition based on edibility and resistance to digestion. The broadened definition included all digestion-resistant polysaccharides (mostly plant storage saccharides, such as gums, modified celluloses, mucilages, oligosaccharides and pectins). Thus, dietary fiber consisted of cellulose, hemicellulose, lignin, gums, modified celluloses, mucilages, oligosaccharides and pectins and associated minor substances such as waxes, cutin and suberin (1, 4-5, 10, 13-15, 31). Some of the nondigestible polysaccharides were included in the definition.
because they were found to have the physiological actions attributed to DF, but could not necessarily be chemically identified as having their origins in the cell wall (1).

Therefore, the updated definition of DF by the American Association of Cereal Chemist (AACC) is "the edible parts of plants or analogous carbohydrates that are resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the large intestine. DF includes polysaccharides, oligosaccharides, lignin, and associated plant substances. Dietary fibers promote beneficial physiological effects including laxation, and/or blood cholesterol attenuation, and/or blood glucose attenuation" (1-6).

As a result relatively few changes will be necessary in analytical methodology. Current methodologies, in particular AACC Approved Method of Analysis 32-05 (AOAC 985.29) or AACC 32-07 (AOAC 991.43) will continue to be sufficient and used for most foods. A small number of additional methods will be necessary to quantitate the DF levels in foods containing fibers such as fructans (polymers and oligomers of fructose, inulin), dextrins, and/or synthetic DF analogues (1-2, 4).

2.1.2 DF components and classification

2.1.2.1 DF components

DF includes all non-starch polysaccharides resistant to digestion in the small intestine and fermentable in the large intestine, as follows

a. Non-starch polysaccharides and resistant oligosaccharides include celluloses, hemicelluloses such as arabinoxylans and arabinogalactans, pectin, modified celluloses, fructans (oligomers and polymers of fructose, i.e. inulin), gums and
mucilages. Oligosaccharides, such as oligofructans, include the lower molecular weight analogues of the digestion-resistant polysaccharides.

b. **Analogous carbohydrates** i.e. polysaccharides having the digestion resistance, fermentation and physiological properties of naturally sourced dietary fibers, are included.

c. **Lignin and the plant substances** associated with the non-starch polysaccharides are an integral part of the fibrous portion of plants. Lignin, a polyfunctional polymer is intimately formed with and infiltrates the cellulose of plant cell wall and is very resistant to digestion, even with strong acid. Likewise *waxes* and *cutin*, found as waxy layers at the surface of the cell walls, are made up of high hydrophobic, long chain hydroxy aliphatic fatty acids and are resistant to digestion and probably render the associated tissues resistant to digestion. *Suberin*, while not well characterized, is hypothesized to be a highly branched and cross-linked combination of polyfunctional phenolics, polyfunctional hydroxyacids and dicarboxylic acids that are likely linked to the cell wall with ester linkages. Evidence of its intimate interaction with other DF components is the fact that only suberin-enriched fractions, but never purified suberin, have been prepared. And finally, *phytate* (phytic acid), *tannins* and *saponins* that are part of the DF complex are included (1, 5). The constituents of DF are summarized in the Table 1.
Table 1 Constituents of DF (1)

<table>
<thead>
<tr>
<th>Non-starch polysaccharides and resistant oligosaccharides</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cellulose</td>
</tr>
<tr>
<td>Hemicellulose</td>
</tr>
<tr>
<td>Arabinoxylans</td>
</tr>
<tr>
<td>Arabinogalactans</td>
</tr>
<tr>
<td>Polyfructoses</td>
</tr>
<tr>
<td>Inulin</td>
</tr>
<tr>
<td>Oligofructans</td>
</tr>
<tr>
<td>Galactooligosaccharides</td>
</tr>
<tr>
<td>Gums</td>
</tr>
<tr>
<td>Mucilages</td>
</tr>
<tr>
<td>Pectins</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Analogous carbohydrates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indigestible dextrins</td>
</tr>
<tr>
<td>Resistant maltodextrins (from corn and other sources)</td>
</tr>
<tr>
<td>Resistant potato dextrins</td>
</tr>
<tr>
<td>Synthesized carbohydrate compounds</td>
</tr>
<tr>
<td>Polydextrose</td>
</tr>
<tr>
<td>Methyl cellulose</td>
</tr>
<tr>
<td>Hydroxypropylmethyl cellulose</td>
</tr>
<tr>
<td>Indigestible (“resistant”) starches</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lignin substances associated with the non-starch polysaccharide</th>
</tr>
</thead>
<tbody>
<tr>
<td>And lignin complex in plants</td>
</tr>
<tr>
<td>Waxes</td>
</tr>
<tr>
<td>Phytate</td>
</tr>
<tr>
<td>Cutin</td>
</tr>
<tr>
<td>Saponins</td>
</tr>
<tr>
<td>Suberin</td>
</tr>
<tr>
<td>Tannins</td>
</tr>
</tbody>
</table>

2.1.2.2 Classification of DF

In general fiber is defined according to its solubility in water into insoluble (IDF) and soluble fiber (SDF) (7-14).

IDF is plant material that is not digestible by appropriately chosen enzymes that mimic the human alimentary system and is not soluble in hot water.

SDF is food material that is not digestible by appropriately chosen enzymes and is soluble in warm or hot water, but is reprecipitated when that water is premixed with four parts of ethyl alcohol (14).
Table 2 Soluble and insoluble components of DF (30-31)

<table>
<thead>
<tr>
<th>Insoluble components</th>
<th>Soluble components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cutin</td>
<td>Pectins</td>
</tr>
<tr>
<td>Hemicellulose</td>
<td>Hemicellulose</td>
</tr>
<tr>
<td>Cellulose</td>
<td>Gums</td>
</tr>
<tr>
<td>Lignin</td>
<td>Mucilages</td>
</tr>
<tr>
<td>Wax</td>
<td></td>
</tr>
</tbody>
</table>

**a. IDF components**

*Cellulose* is probably the least soluble of all fiber components, being insoluble not only in cold or hot water, but also in hot dilute acid and alkaline as well (14). Cellulose, the major cell wall structural component in plants, is an unbranched linear chain of several thousand glucose units with β-D-(1→4)-glucosidic linkages (14, 29, 31, 34-35). The 1,4 β linkage allows the cellulose polymer to crystallize in a linear configuration, with a high degree of intermolecular hydrogen bonding, which gives it substantial shear and tensile strength (14). The β glucosidic bond between the 1,4 linkage of the glucose units can only be broken down by strong mineral acids and cellulase enzyme. Thus cellulose is not hydrolyzed in the human digestive system and this property makes cellulose a true unavailable carbohydrate (31, 34). Controlled acid hydrolysis of the amorphous fraction yield microcrystalline cellulose. Cellulose has been used as bulking agent in food due to its water-absorbing ability and low solubility. Some of the early dietary fiber ingredient sources were based on cellulose powders or microcrystalline cellulose (31).

*Hemicellulose* may present in soluble and insoluble forms and are comprised of a number of branched and linear pentose- and hexose-containing polysaccharides. In cereal grains, soluble hemicelluloses are termed “pentosans”. Hemicelluloses are of much lower molecular weight than cellulose (31). What
distinguishes hemicellulose from cellulose is the fact that hemicellulose can be dissolved in dilute alkaline (14, 29, 35). Component monosaccharide units may include xylose, arabinose, galactose, mannose, glucose, glucuronic acid and galacturonic acid (14, 31). Both soluble and insoluble hemicelluloses play important roles in food products, the former functioning as SDF and the latter as IDF. They are characterized by their ability to bind water and hence serve as bulking agents. The presence of acidic components in some hemicelluloses impart the capacity to bind cations. Hemicelluloses are fermented to a greater extent than cellulose in the colon (31).

Lignin is an amorphous, highly water-insoluble polymeric material composed of phenylpropane residues which are formed in a matrix type arrangement by the condensation of the phenolic alcohol such as coniferyl, sinapyl and p-coumaryl (14, 29, 34-35). Lignin can bind bile salts and other organic materials and may delay or impair the small intestinal absorption of associated nutrients (14, 35).

Cutin and plant waxes are hydrophobic lipid materials which are typically found in the plant structure, closely associated with the structural polysaccharides or on the outer surface of the plant. They are usually present in very small quantities (14).

b. SDF components

Gums Basically, all SDF are gums from a variety of sources (14). They are complex polysaccharides that are not part of the cell wall structure. Nevertheless, because they are generally indigestible, they are considered a DF (36). Plant gums are sticky exudates formed at the site of injury to plants. These gums present a complex group of highly branched uronic acid containing polymers, mainly of glucoronic and galacturonic acids, with neutral sugars such as xylose, arabinose and mannose (14, 36-35).
These compounds are long-chain polymers which dissolve or disperse in water to give a thickening or viscosity-building effect. Most gums come from plant materials such as seaweed (alginites, agar, carrageenan), seeds (locust bean gum, guar gum) and tree exudates (gum arabic, gum ghatti, gum karaya, gum tragacanth); others are products of microbial biosynthesis (xanthan gum, gellan gum); and still others are produced by chemical modification of natural polysaccharides (cellulose derivatives, pectin) (31, 38).

**β-glucans** Most of the β-glucan present is soluble although a small amount may be insoluble. β-glucans are glucose polymers containing un-branched β-1,4 linked D-glucose units interdispersed with β-1,3 linkages. They commonly occur in the endosperm and aleurone cell wall of cereals. The highest concentrations are found in barley, rye, and oats (35). The amount of the β-glucan and ratio between 1,4 and 1,3 linkage decreases with the maturity the cell walls but typically the ratio is between 2 and 3 to 1 (14, 31).

**Pectins** are polymeric substances that are based on a polymer of D-galacturonic acid, linked by α-1,4 linkages. The main polymer has side chains that consist of the sugars; galactose, glucose, rhamnose and arabinose. Pectins are primarily water-soluble, solubility being somewhat dependent on the degree of esterification of the galacturonic acid, as well as the make up of the constituent side chains. The primary sources of pectin are citrus fruits and apples, although sugar beet pulp also has a high content of this polymer (14, 34). Pectins find widespread use in foods such as jams and jellies because of their ability to form stable gels. The presence of calcium salts enhances the gelling capacity and decreases the dependence on pH and sugar concentration. Pectic substances are of importance as a component of DF because of
their ion-exchange properties, due to the presence of the galacturonic acid units, and
gelling (viscosity enhancing) properties (31).

*Mucilages and algal polysaccharides* are found in different parts of the
plant. They are usually mixed in with the endosperm or storage polysaccharides of
plant seeds. Their role is to retain water and protect the seed against desiccation. The
algal polysaccharides are found in algae and seaweeds. Both mucilages and algal
polysaccharides are used in small amounts in the food industry as thickening and
stabilizing agents by virtue of their water-holding capacity and viscous properties (31, 34).

### 2.1.3 Chemical-physical properties

In order to understand the role of DF in human body, it is necessary to know
the properties of each DF component. Some DF sources possess unique properties that
appear to have a relationship to physiological response. Some of these properties and
the physiological response elicited by specific fiber fractions are described below and
summarized in Table 3.

**Table 3** Physiological responses affected by the physical properties of DF fractions
(29).

<table>
<thead>
<tr>
<th>Physical property</th>
<th>DF fraction</th>
<th>Physiological response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacterial degradation</td>
<td>Polysaccharides</td>
<td>Production of SCFAs, flatulence, and acidity</td>
</tr>
<tr>
<td>Water-holding capacity</td>
<td>Polysaccharides</td>
<td>Effect on nutrient absorption, fecal weight, and rate of transit in stomach and small intestine</td>
</tr>
<tr>
<td></td>
<td>with polar groups</td>
<td></td>
</tr>
<tr>
<td>Adsorption of organic</td>
<td>Lignin</td>
<td>Binding and excretion of bile acid</td>
</tr>
<tr>
<td>Materials</td>
<td>Pectin</td>
<td></td>
</tr>
<tr>
<td>Cation exchange</td>
<td>Acidic</td>
<td>Increase in mineral excretion</td>
</tr>
<tr>
<td></td>
<td>polysaccharides</td>
<td></td>
</tr>
</tbody>
</table>
2.1.3.1 Bacterial degradation

DF cannot be enzymatically degraded in the human small intestine. However, it is fermented to varying degrees by the microflora which naturally occur in the large intestine. The degree of degradation varies considerably among the polysaccharides and depends on many factors such as types, components and polysaccharide structure of DF, water-holding capacity, physical structure of plant and kinds of bacterial flora in large intestine. For example, pectins, mucilages, and gums appear to be completely degraded, whereas, cellulose is only partially broken down. Furthermore, DF from fruits and vegetables appear to be more fermentable than that from cereals and nuts. The extent of bacterial degradation has several potential consequences;

- Short-chain fatty acids (SCFAs) produced during bacterial metabolism may influence physiological responses to fiber, for example, SCFAs can be used by cells in the colon for energy, and absorption of SCFAs may influence hepatic metabolism of lipid and glucose.

- The fermentation process may lower the pH of the large bowel and affect the activity of bacterial enzymes.

- Bacterial cell mass can account for a significant portion of the fecal weight and thus contribute to fecal bulk (17, 29, 34-35).

2.1.3.2 Water-holding capacity (WHC)

WHC is significantly enhanced on polysaccharides by the presence of sugar residue with free polar groups. Cellulose and lignin are insoluble and have a relatively low WHC. In contrast, pectins, gums, β-glucans, mucilages and some hemicellulosides have a high WHC. Hydration of the DF results in the formation of the gel matrix. This
can raise the viscosity of gastrointestinal contents and partition some water soluble nutrients into the gel matrix and, as a consequence, slow gastric emptying and the diffusion and absorption of the nutrients. Although WHC has also been related to increase fecal bulk, the relationship is not straightforward because of the bacterial degradation of DF within the colon. Typically a higher WHC is associated with greater fermentability of the fiber sources by allowing greater penetration of microbes into polysaccharide structure (17, 29, 34-35).

2.1.3.3 Adsorption of organic materials

Adsorption of organic materials including bile acids, cholesterol, and toxic compounds is the third interesting physical property of DF. *In vitro* studies have demonstrated that lignin is an effective bile acid adsorbent. Pectin and other acidic polysaccharides also seem to sequester bile acids. Cellulose, in contrast, has little bile acid binding ability. Bile acid adsorption is measured *in vivo* as the ability to increase fecal bile acid and steroid excretion. The ability to increase fecal bile acid excretion has been correlated to the plasma cholesterol-lowering effect of certain soluble, non-cellulose polysaccharides, such as pectin, oat bran, guar gum, and psyllium. Although the ability of some DF to bind toxic compounds has not been extensively studied, it has been proposed as a protective mechanism of the DF against gastrointestinal cancers (17, 29, 35).

2.1.3.4 Cation exchange capacity

The reduced mineral availability and electrolyte absorption associated with certain high-fiber diets are undoubtedly due to the binding of minerals and electrolytes on fiber sources, resulting in increased fecal excretion of minerals and electrolytes. The number of free carboxyl groups on the sugar residues and uronic acid content of
polysaccharides appear to be related to the cation exchange properties of DF (17, 29, 35).

2.1.3.5 Particle size

The degree to which the cell wall matrix, which is rich in DF components, is disrupted by grinding to a finer particle size will influence the physiological response to fiber sources. The fermentability of DF is influenced by particle size. Likewise, if the cell wall is completely intact, digestive enzymes may penetrate and release nutrients from the food slower than if the cell wall has been disrupted by grinding (19, 35).

2.1.4 Physiological effects

DF has been reported to have several physiological effects, depending upon the physical and chemical properties of the individual DF sources. These effects include increasing fecal bulk and improving large bowel function, decreasing nutrient availability, reducing levels of plasma cholesterol, and reducing glycemic responses to a meal. Some DF sources are more effective than others in eliciting these responses. Table 4 shows results from several studies demonstrating that fecal bulk is increased by various DF supplements.

Factors contributing to increased fecal bulk include the presence of undegraded DF residue, an increase in fecal water content, and an increase in microbial cell mass arising from the fermentation of DF. Coarsely ground wheat bran, reported to increase fecal wet weight 80-120%, is the most effective DF source. In contrast, finely ground wheat bran, with its disrupted physical structure, exhibits less bulking action than coarsely ground wheat bran, probably because its water-holding capacity has changed or
is more readily degraded by bacteria. In this instance, the physical form of the DF source is as important as the amount of DF in eliciting a physiological response.

In addition to differences in physical forms, specific DF sources differ in their bulking ability. Data indicated that the sources of soluble, non-cellulose polysaccharides, such as pectin and gums, tend to be less effective fecal bulking agents, because they are completely degraded by bacteria within the large bowel. However, fruits and vegetables are effective in increasing fecal weight because they contribute both to increased DF residue and microbial mass (29, 35).

Table 4 Fecal bulk associated with DF supplements (29, 35)

<table>
<thead>
<tr>
<th>DF source</th>
<th>% Increase in fecal wet weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oat bran</td>
<td>15</td>
</tr>
<tr>
<td>Pectin</td>
<td>16-35</td>
</tr>
<tr>
<td>Guar gum</td>
<td>20</td>
</tr>
<tr>
<td>Apple</td>
<td>40</td>
</tr>
<tr>
<td>Carrot</td>
<td>59</td>
</tr>
<tr>
<td>Cabbage</td>
<td>67</td>
</tr>
<tr>
<td>Cellulose</td>
<td>75</td>
</tr>
<tr>
<td>Wheat bran, coarse</td>
<td>80-127</td>
</tr>
<tr>
<td>Wheat bran, fine</td>
<td>24</td>
</tr>
</tbody>
</table>

Another effect of DF on large bowel function is to decrease transit time which is the time for a marker to pass in the feces after consumption. Addition of fruits and vegetables or wheat bran to human diets but not pectins or gums, have been shown to shorten transit time. Transit time and stool weight are inversely related, however, once a transit time of 20-30 hours is reached, further increases in stool weight do not substantially shorten transit time. Further definition of the effects of DF on these two parameters may allow better assessment of the adequacy of DF intake with respect to maintaining normal physiological function.
As shown in Table 5, sources of non-cellulose polysaccharides that are viscous appeared to be most effective in reducing plasma cholesterol levels which resulting from capacity of binding bile acid, an effect readily demonstrated in hyperlipidemic individuals. Food formulated with gums for treatment of hypercholesterolemia have been tested. These studies suggested that the formulated foods are palatable to the individual and effective in treatment of the disorder (29).

Table 5 Effect of DF sources on plasma cholesterol levels (29)

<table>
<thead>
<tr>
<th>Source of DF</th>
<th>Quantity of DF ingestion (g/day)</th>
<th>%Reduction in cholesterol level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cellulose</td>
<td>16</td>
<td>0</td>
</tr>
<tr>
<td>Wheat bran</td>
<td>17</td>
<td>1</td>
</tr>
<tr>
<td>Whole oats</td>
<td>15</td>
<td>11</td>
</tr>
<tr>
<td>Oat bran</td>
<td>27</td>
<td>17</td>
</tr>
<tr>
<td>Pectin</td>
<td>25</td>
<td>13</td>
</tr>
<tr>
<td>Guar gum</td>
<td>24</td>
<td>16</td>
</tr>
<tr>
<td>Bran</td>
<td>30</td>
<td>19</td>
</tr>
</tbody>
</table>

The percent increase in plasma glucose can be reduced when sources of viscous polysaccharides are mixed with a glucose load in a glucose tolerance test. In a food system, the presence of DF may attenuate the plasma glucose and insulin response to a meal, however, the interactions are clearly more complex than those observed in the glucose tolerance test.

Some concern has been raised that sources of DF can lower the availability of minerals. Although consumption of high DF diets may increase fecal mineral excretion, the nutritional consequences will depend on the overall adequacy of mineral intake and the total amount of DF consumed. Any recommendations for increasing DF intake should be limited if mineral balance is not compromised. Table 6 shows some of the physico-chemical properties of DF and the gastrointestinal events it may modify (39).
Table 6 Physico-chemical, physiological and clinical aspects of DFs (39)

<table>
<thead>
<tr>
<th>Physicochemical Property</th>
<th>Type of DF</th>
<th>Physiological Effect</th>
<th>Clinical Implication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle size and WHC</td>
<td>Wheat bran, Pentosan content, Polysaccharides, Lignin mixtures</td>
<td>↑Gastric emptying, ↓Mouth to cecum transit, ↓Total gastrointestinal tract transit time, ↓Colonic intraluminal pressure, ↑Fecal bulk</td>
<td>Peptic ulcer, Constipation, Diverticular disease, Dilute potential carcinogens</td>
</tr>
<tr>
<td></td>
<td>Cation exchange: Acidic polysaccharides (e.g. pectins)</td>
<td>Tend to increase small intestinal losses of minerals, trace elements, heavy metals</td>
<td>Negative mineral balance, possibly compensated for by colonic salvage, antitoxic effect</td>
</tr>
<tr>
<td></td>
<td>Antioxidant: Lignin (reducing phenolic groups)</td>
<td>↓Free radicals in digestive tract</td>
<td>Anticarcinogenesis</td>
</tr>
<tr>
<td></td>
<td>Degradability (colonic bacteria): Polysaccharides (free of lignin)</td>
<td>↑Production of gas and SCFAs, ↓Cecal pH</td>
<td>Flatus, energy production</td>
</tr>
<tr>
<td></td>
<td>Absorption and nonspecific effects: Lignin, Pectin mixed DF</td>
<td>↑Fecal steroid output, ↑Fecal fat and N losses (small)</td>
<td>Hypercholesterolemia, Cholelithiasis</td>
</tr>
<tr>
<td></td>
<td>Viscosity: Gums, Mucilages, Pectins</td>
<td>↓Gastric emptying, ↑Mouth to cecum transit, ↓Rate of small intestinal absorption (e.g. of glucose, bile acid)</td>
<td>Dumping syndrome, Diabetes, Hypercholesterolemia</td>
</tr>
</tbody>
</table>

↑ = increase, ↓ = decrease
2.1.5 DF in health and disease

The hypothesis that fiber has protective effects against many diseases has been under investigation for many years. There is much epidemiological evidence of its role in disease prevention. An inverse relationship between fiber intake and the incidence of obesity, heart disease, cancer (particularly colon and breast), diabetes and gastrointestinal disorders has been documented (11).

2.1.5.1 Obesity

Obesity is associated with an increased risk of many chronic diseases such as diabetes, hypertension, coronary artery disease, gall bladder disease and some types of cancer. Epidemiological observation suggests that higher-fiber diets are lower in energy and less likely to contribute to the development of obesity. They tend to be bulky and also to induce satiety. High-fiber diets may promote long-term weight loss and maintenance for this and other reasons. They take longer to eat increasing satiety and satisfaction. They slow gastric emptying, contributing to a feeling of fullness. They decrease the absorption of nutrients, thus total energy intake may be limited. They also lower serum insulin, enhancing satiety, since insulin is known to stimulate appetite (11-12, 14, 34, 40).

2.1.5.2 Coronary heart disease

Several studies in human populations have found inverse correlations between intakes of DF from foods and risk of coronary heart disease. Some researches have therefore speculated that fiber might also help to prevent heart disease in other ways—perhaps by effects on obesity, blood coagulation or glucose metabolism, or by a direct effect on the development of arteriosclerosis (12). High fiber food containing high amounts of complex carbohydrates have been useful in blood lipids, blood glucose
and insulin response. SDF has been shown to reduce risk of cardiovascular disease and to reduce the rise in blood glucose and insulin following carbohydrate meal (11, 40-42). There also is some evidence that SDF tend to lower low-density lipoprotein cholesterol (LDL) without increasing serum triglyceride levels (11, 34). Furthermore, several researchers indicated that SDF such as oat bran or dry bean may also increase high-density lipoprotein cholesterol (HDL) concentration in hypercholesterolemic men (34, 43-44). The degree of hypocholesterolemic response seems to be related to the type of dietary fiber and the degree of hypercholesterolemia in the patients (45).

2.1.5.3 Colon cancer

Several mechanisms have been proposed for fiber's protective effect against colon cancer. Fiber may act to reduce transit time in the colon and thereby decrease the time for exposure to potential carcinogens. Through its hydrophilic nature, fiber can dilute the concentration of carcinogens in the colon. It can affect the production of bile acids and other potential carcinogens in the stool, it can alter the nature of faecal bile acids by virtue of its influence on the constitution and metabolic activity of faecal bacteria, and it can reduce colonic pH by increasing fermentation and short-chain fatty acid production (11-12, 14, 40).

2.1.5.4 Diabetes

DF may offer many health benefits for diabetics. High fiber intake lowers fasting postprandial plasma glucose and insulin levels, reduces insulin requirements, and improves glycemic blood sugar control. It also lowers serum cholesterol and triglyceride values in diabetic individuals. Because diabetes accelerates arteriosclerosis, maintenance of normal serum lipid levels is a primary goal in diabetes management (11, 14).
2.1.5.5 Gastrointestinal disorder

Fiber is necessary to maintain normal functioning of the gastrointestinal tract (11, 46). One of the most consistent effects of DF is to increase fecal weight and water holding capacity, thereby making the stool softer and bulkier (11, 14, 34). Conversely, a lack of DF appears to be one of the major causes of a wide variety of bowel disorders such as constipation, diverticular disease (14, 34).

a. Constipation is a very common problem particularly amongst children, pregnant woman and the elderly. In particular IDF has been used in the prevention and treatment of constipation (11-12, 14, 34).

b. Diverticular disease is now widely accepted as being the direct result of a low-residue diet. When unnaturally strong muscle contractions try to propel the firm fecal masses along the colon, pressures are built up within the lumen. These pressures blow out the diverticular (47). Unfortunately it was formerly believed that a high-roughage diet irritated the colon and consequently a low-fiber diet was prescribed for the treatment of this condition. Now that a lower fiber diet is known to be the cause of the disease, a high-fiber diet is becoming the standard treatment.

2.1.6 Possible adverse effects of DF

The consumption of moderate quantities of DF from food is generally believed to be safe (12). Even though DF have benefits on health, over consumption of fiber brings about potential adverse effects. Some adverse effects may occur with the consumption of 50-60 g fiber diets (48). Anyone changing suddenly from a low-fiber to a high-fiber diet is liable to diarrhea and also flatulence. These side effects are caused by bacterial fermentation of fiber with release of volatile fatty acids, hydrogen, carbon
dioxide and methane. Therefore, an increase in DF intake should be gradual and accompanied by adequate fluid intake so the gastrointestinal tract can adjust to the change (12, 14-15, 32, 49).

Substances found in fiber or associated with fiber may bind to nutritionally important minerals (12). The effect of DF on mineral balances continues to be a controversial issue since a number of studies have demonstrated reduced or even negative mineral balance with the intake of certain fiber at moderate to high levels. The mechanism by which DF influences mineral absorption is related to the ability of DF to act as weak cation exchanger, decrease transit time, dilute mineral concentration by increasing fecal bulk and resisting digestion in the large bowel. Many other factors in addition to DF can affect the absorption of minerals (34) such as the use of mineral supplements, the level of mineral intake, the length of study period, the health status of the subjects, and the presence of other dietary constituents which may impair (phytate and oxalate) or enhance (ascorbate or citrate) absorption. Unfortunately, these factors are not always controlled in metabolic studies so inconsistencies are inevitable.

On vitamins, few studies have been reported that riboflavin and niacin may not be as easily absorbed from whole wheat bread as from enriched white bread. Nicotinic acid bound to cellulose in cereal bran may not be readily available and wheat bran is shown to decrease vitamin B6 availability (14, 48).

In term of purified DF, it may reduce acutely the absorption of some vitamins and minerals by binding or entrapping them in the intestinal lumen, however, there is a little evidence that population groups consuming nutritionally adequate diets rich in high fiber foods, such as vegetarian, have any problems with vitamin or mineral deficiencies. Recent studies with calcium suggested that purified fibers reduce calcium
availability in the small intestine, but that at least some of the calcium carried into the colon, bound to or entrapped by fiber, was released when the fiber was fermented with the short chain fatty acid products of digestion facilitating calcium absorption from the distal colon and rectum (31).

2.1.7 DF recommendation

Consumption of DF has become a topic of increased interest. More than 40% of American and Australian shoppers and one-third of Western European and Indian shoppers say "high fiber" claims are extremely very important on food labels (50). General recommendations are to increase consumption of fruits, vegetables and cereal products, replacing energy intakes from fatty or sugary foods. However, dietary recommendations for fiber must take into account several factors:

- Physiological effects of various fiber components
- Long-term effects of fiber on health and disease
- Potential adverse effects of mineral availability in more susceptible populations
- The intended population for the recommendation
- Current intake levels to assess feasibility of the recommended level
- Whether DF will be consumed in foods or supplements (10).

The two main types of DF, SDF and IDF have some different mechanisms of action in vivo (10-11, 21). Both types of fiber complement each other and a 70-50% IDF and 30-50% SDF is considered a well-balanced proportion (21). The National Cancer Institute (USA) suggested a daily intake of 20 to 30 g, with a maximum of 35 g (43). Moreover, DF intake should consist of equal amounts of SDF and IDF.
According to the Healthy Competition Foundation, their recommendation is 20 to 25 g/day of TDF intake, with approximately one third of that as SDF (14). The Thai Recommended Daily Intake (Thai RDI) for population over 6 years old stated that people should consume 25 g/d DF based on a 2000 kcal/day intake (51).

2.1.8 DF sources

DF occurs naturally in all plants and is available for the human diet through a wide variety of food sources such as whole-grain cereals, vegetables, fruits, legumes, nuts, prepared foods (which may include gums or other fiber additives), and dietary supplements (34).

Most foods of plant origin, however, contain both soluble and insoluble fiber, but they tend to be rich in one type of fiber. The major food sources of insoluble fiber are wheat products, most grains and vegetables. The major food sources of SDF are fruits, oats, barley, bean and psyllium (11, 32).

Table 7 Major food sources of DF components (11)

<table>
<thead>
<tr>
<th>Type</th>
<th>Component</th>
<th>Major food sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>IDF</td>
<td>Lignin</td>
<td>Wheat</td>
</tr>
<tr>
<td></td>
<td>Cellulose</td>
<td>Most grains</td>
</tr>
<tr>
<td></td>
<td>Hemicellulose</td>
<td>Vegetables</td>
</tr>
<tr>
<td>SDF</td>
<td>Pectins</td>
<td>Fruits</td>
</tr>
<tr>
<td></td>
<td>Gums</td>
<td>Oats</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Barley</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Beans</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Psyllium</td>
</tr>
</tbody>
</table>

2.1.8.1 Soybean hulls (SBH)

In Thailand, soybean production is mainly for domestic consumption in terms of grain, oil and meal (52). There was 324,000 tons of soybean production in 2000 (53). The seed coat of soybeans, also known as soybean hulls that remains in a
large quantity as a waste from soy processing are by products which have been overlooked and used as fillers in animal diets and as a fiber supplement (54-55).

Dry SBH contain about 85.7% carbohydrates, 9% protein, 4.3% ash and 1% lipid. At present, SBH are primarily used for animal feed. Since soy carbohydrates are mainly composed of α-cellulose and hemicellulose, being low in lignin, they are easily digested by animals. In fact, they are so highly digested that their digestible energy content is essentially equal to grains (56). In addition, Arpanantikul (1993) reported that SBH could be one of DF sources because of its high DF content. Moreover, SBH contained low levels of antinutritional factors which would not give any adverse effect to consumer (28).

As reported by Kiattheerachai, SBH contain 75.2% of TDF which consist of 66.4% of IDF and 8.8% of SDF (57). So, SBH have been used as a fiber supplement for bakery products (28, 55, 57-58), Thai traditional sweets (28), snack bars (59) and fresh wheat noodles (60-61).

2.1.8.2 Carrageenan

Carrageenans are sulfated polymers which consist of galactose and anhydrogalactose units. The gums are extracted from the red seaweeds and are divided into three main types: kappa, iota and lambda. Kappa and iota carrageenan, except in the sodium form, are not soluble in cold water and require heating for dissolution. In the presence of potassium ions and upon cooling, kappa carrageenan forms a brittle gel characterized by syneresis. Iota carrageenan, in the presence of calcium ions, form elastic, syneresis-free gels. Lambda carrageenan is soluble in cold water and is nongelling. Carrageenan is a yellowish or tan to white powder that is practically odorless and has a mucilaginous taste. It has been used for its gelling, thickening,
stabilizing, emulsifying and suspending properties. Because of its reactivity with certain proteins, the gum has found used at low concentrations (typically 0.01 to 0.03%) in a number of milk-based products such as chocolate milk, ice cream, puddings and cheese analogues (34, 38, 62).

2.1.8.3 Sodium carboxymethylcellulose (CMC)

Sodium carboxymethylcellulose which is more commonly called cellulose gum or CMC is available in variety of types based on particle size, degree of substitution, viscosity and hydration characteristics. Solutions of the gum exhibit pseudoplasticity—i.e., time-independent, shear-thinning behavior. Viscosity decreases with an increase in temperature and is stable over the pH range of 4 to 10. The basic function of CMC is to bind water or add viscosity to the aqueous system, to stabilize other ingredients, and/or to prevent syneresis. The gum is generally used to thicken, suspend, stabilize, gel and modify flow characteristics of aqueous solutions or suspensions. CMC has been used in a low-calorie foods as a bulking agent (34, 38).

2.1.8.4 Konjac flour

Konjac flour or konjac powder is the dried, pulverized and winnowed tubers of the perennial herb Amorphophallus konjac. The dried tuber of the konjac plant contains about 60-80% konjac flour, which can be obtained by wet or dry milling. The flour consists of fine oval whitish sacs—100 to 500 microns in size—which swell in contact with water and rupture to release a high molecular weight water-soluble aggregated glucomannan. Konjac flour contains a high molecular weight glucomannan consisting of mannose and glucose in a molar ratio of approximately 3:2, respectively, with β-1,4-linkages. The molecular weight is greater than 300,000 daltons. Acetyl groups are scattered randomly along the essentially linear molecule with an occurrence...
of approximately 1 per 19 glucose/mannose units. The acetyl groups impart water solubility in an otherwise amylose-like molecule. Traditionally, konjac solutions are cooked with a mild alkaline to produce thermally stable gels. Mild alkaline cleaves acetyl groups reducing water solubility, allowing a three dimensional hydrogen bonded network to form. This gel network has remarkable stability in hot and cold acid and alkaline systems. Konjac flour has a variety of existing and potential food applications: reduced-fat food, sausage-like products, reduced-fat condiment and pasta products (63-64).

2.2 Instant noodle products

2.2.1 Definition

Instant noodles, mainly made from wheat flour or blend of rice and mungbean flours, are sold in single servings in pouches or cups, with a separate sachet containing the seasonings. Unlike traditional noodles which have to be boiled for 10-15 minutes to gelatinize the starch, instant noodles are prepared by adding boiling water. They are ready for consumption in 3-5 min. The steaming and frying processes during instant noodle production gelatinize the starch and allow it to be consumed after rehydration (65-68).

2.2.2 Noodle ingredients and their functions

2.2.2.1 Flour and starch

Wheat flour is one of the main ingredients of noodles, and wheat quality greatly influences the final product. Typical types include dark northern spring (13 % protein), hard red winter (11.5-13.3 % protein) and Australian standard white (10 %
protein). For Thailand, all purpose wheat flour, which contained 10-11% protein, was used in noodle production.

Noodles also contain starches that contribute to texture improvement. Potato, waxy corn, barley, rice and tapioca are often used. Modified starches are used in some applications.

a. Wheat flour

Wheat flour is a powdery substance produced by finely grinding wheat through a process called milling. It is used in many food products such as bakery and noodle products. Flour is composed of starch, protein, and small amounts of fat, sugar, and minerals. The protein in wheat flour is called gluten. It forms the framework of the baked products and makes the dough sticky. As the mixing of the dough proceeds, the gluten in the flour becomes elastic and pliable. When the dough is heated, the gluten coagulates, or becomes firm. It forms, along with the starch, the structure of the product. All flours do not have the same amount of gluten. Flour with very little gluten called soft flour is milled from soft white wheat. Soft flour is particularly good for making cookies and cakes. High protein contents lead to hardness of texture and coarseness of internal grain and surface appearance. On the other hand, if the flour is decreased too much, as when large amounts of enriching ingredients are added, the products will lack body and become too fragile (25, 68, 72-74).

b. Starch

Starch is the most important, abundant, digestible food polysaccharide. Common food starch are derived from seed and root. Starch have been modified to improve desired functional characteristics and are added in relatively small amounts to
food as food additives. Starch is a homopolysaccharide composed only of glucose units and consists of a mixture of two polymers, amylose (linear polymer) and amylopectin (highly branched polymer). Starch granules are not water soluble but easily hydrate in an aqueous solution. When an aqueous suspension of granules is heated, additional swelling occurs until a temperature is reached where there is a transition from organization to disorganization. This is known as the gelatinization temperature. Upon further heating, swelling continues and the amylose and portions of the amylopectin are leached from granule producing a viscous suspension. Cooling of this suspension leads to the formation of a gel. With further time, realignment of the linear chains of amylose and the short chains of amylopectin can occur in the process known as retrogradation. In food products based on starch gels, this can lead to liquid being expressed from the gel in the phenomenon known as syneresis, which is generally an undesirable occurrence (31, 75).

2.2.2.2 Water

When water is added to the wheat flour and kneaded, the gluten network develops, which contributes to viscoelastic properties of the dough and increases the smoothness of the noodle surface (68-71).

2.2.2.3 Salt and kansui

a. Salt has direct effect on characteristic of gluten in dough by increasing dough strength and preventing dampness. It enhances flavor, improves texture and decreases the boiling time. In addition, salt also can preserve the noodles.

b. Kansui is an alkaline salt that can include potassium carbonate, sodium carbonate and phosphates of sodium and potassium. Kansui interacts with the
gluten, producing a gumlike texture that is typical of noodle texture. It also contributes to the development of the yellow color and enhances the flavor (68-71).

2.2.2.4 Other ingredients

a. Gluten

The principal functional protein of wheat flour is gluten which consists of glutenins and gliadins. Generally, glutenins contribute to dough elasticity whereas gliadins contribute to dough viscosity. High molecular weight glutenin subunits join end-to-end through disulfide bonds to provide a sort of backbone to gluten complex. Low molecular weight glutenin subunits are also crosslinked through disulfide bonds into the protein network. The smaller spherical gliadin molecules are incorporated into gluten primarily through noncovalent (hydrogen and hydrophobic) bonds. When flour is hydrated and mixed to form a dough, disulfide bonds may be rearranged as proteins align and as gluten forms. Gluten can be isolated from wheat flour by making a dough with water and then slowly manipulating this dough under a continuous stream of water (71-72, 76-77).

b. Sodium tripolyphosphate (STPP)

STPP inhibits enzyme protease in the flour. Enzyme protease affects elasticity of noodles making them too soft and fragile. Thus, STPP increases the strength and elasticity of dough (78).

c. Guar gum

Guar gum is a high molecular weight galactomannan derived from the seed of *Cyamopsis tetragonolobus*. It is a white to yellowish white, tasteless and odorless powder. It is dispersible in either hot or cold water, forming a solution with a pH of between 5.4 and 7.0. Furthermore, it has a unique ability to hydrate rapidly in
cold water to form very viscous colloidal dispersions. Guar gum is non-gelling and is used chiefly as a viscosity builder, stabilizer and water binder (14, 34, 38).

2.2.3 Instant noodle production

Ingredients other than flour are pre-dissolved in water (preferably soft water) and mixed with wheat flour. The mixing time for common noodles is about 17 min. After mixing, the crumbly dough pieces are compressed into a continuous sheet by repeated passage through pairs of rolls and folded. The folded sheet is successively reduced to the desired thickness and cut into noodles. Then, the cut noodle strands are continually fed into a traveling net conveyor, which moves slower than the cutting rolls above it. The speed differential between noodle feeding and net traveling gives the noodle strands a unique wave. After that, the wavy noodle strands are steamed and cut into one serving size. Then, they are placed in a mold and fried at 145-150°C, 60-70 sec for bag noodles and 157-160°C, 90-120 sec for cup noodles. The fried noodles are cooled and packed in bag or cup packaging (66, 69-70).

2.3 Application of DF in noodle products

Numerous studies have been made on using additives or substituting some portion of the wheat flour with DF or other ingredients for making noodle product, with varying objectives such as improvement of dough and product properties, nutritional supplementation, or for cost considerations.

In 1993, Hung and Nithianandan fortified lupin and chickpea flours into unsalted white noodles. They investigated the fortification of noodles with lupin flour, chickpea flour and mixture of these two grain flours at substitution levels of 15, 20 and
25%. They found that the fortified products had up to 37% more protein and were particularly high in fiber. The product quality parameters such as color, taste and texture were remarkably improved in the supplemented noodle but suffered from a cooked weight loss which may be improved by pretreatment of the flours used (79).

According to the study by Knuckles et al. (1997), they concluded that addition of β-glucan-enriched barley fraction increased water absorption in both bread and pasta formulas and increased time to peak (farinograph) and mixing for bread doughs. Breads and pastas containing up to 20% dry milled/sieved β-glucan-enriched barley fractions showed acceptable eating quality and were potentially healthful due to increased fiber and reduced calories per serving. Pasta products in which this barley fraction replaced 20% of the standard wheat semolina were considered acceptable and could be labeled as "good" fiber sources since they provided 5.8 g TDF per serving (compared to 2 g in the all-wheat pasta). Kilocalories per serving of these pastas were reduced by 11%. Substitution with water-extractable barley β-glucan fraction yielded breads (5% WS) and pastas (20%) with quality characteristics comparable to the control. Increasing DF in foods by incorporating β-glucan-enriched barley fractions could increase the use of such products in manufactured foods, thus improving the diet of the general population (41).

In 1998, Lee et al. fortified Cantonese noodles with several levels (10, 20, 30%) of garbanzo bean flours with different particle sizes. The experiment showed that both fine and coarse garbanzo bean fractions were successfully incorporated into Cantonese noodles up to the 30% level, with good dough handling properties. Small particles were easier to incorporate and produced more uniform doughs than coarse fractions. Coarse garbanzo bean fractions produced softer noodles than fine fractions.
The lightness of noodle doughs slightly decreased with garbanzo bean substitution and redness and yellowness increased considerably. All texture profile analysis parameters of noodles, besides adhesiveness decreased with garbanzo bean substitution. Cantonese noodles fortified with garbanzo bean flours had higher ash, protein, essential amino acids and DF than those from wheat flour (80).

In 2000, Marconi et al. studied on the composition and utilization of barley pearling by-products for making functional pastas rich in DF and β-glucans. The data showed that the pearling flour fractions contained interesting amounts of β-glucans. These fractions were subsequently enriched in β-glucans using a milling-sieving process to double β-glucan content. Functional pastas, enriched with β-glucans and DF, were produced by substituting 50% of standard durum wheat semolina with β-glucan-enriched barley flour fractions. Although darker than durum wheat pasta, these pastas had good cooking qualities with regard to stickiness, bulkiness, firmness and total organic matter released in rinsing water. The DF and β-glucan contents in the barley pasta were much higher than in the control. These values amply meet the FDA requirements of 5 g of DF and 0.75 g of β-glucans per serving. Given that consumers and manufactures pay greater attention to the physiological benefits of foods, there should be plenty of opportunities for the use of barley by-products in human foods (42).

According to application DF in noodle products in Thailand. In 1992, Siwawej studied on added sorghum traditional rice noodles (kha-nom-jeen) production by replacing sorghum for rice. Results indicated that the highest appropriate amount of rice to be replaced was 40%. The optimum percentage of guar gum to improve the texture of the product was 0.1%. The results also showed that the length of steaming time which allowed 30% of the dough to be cooked was the most appropriate time for
the best texture of the product. In addition it was also found that the nutritive value of sorghum kha-nom-jeen was better than the usual rice kha-nom-jeen (81).

Later in 1993, Siwawej and Suwananchewakorn studied on sorghum vermicelli production by mixing sorghum with broken rice and glutinous rice flour or food additive, then comparisons of the qualities of sorghum vermicelli made from different ratios of the ingredients mentioned were determined. The results showed that the qualities of sorghum vermicelli produced were significantly affected by the percentages of sorghum, broken rice, glutinous rice flour and the food additives used. While the amount of sorghum used increased the acceptability decreased. Addition of certain amount of food additive would help in improving the qualities of sorghum vermicelli. However, the color of sorghum vermicelli were found to be darker than rice vermicelli. (82).

After that, in 1994, Siwawej studied on sorghum macaroni production using various ratios of sorghum flour and wheat flour. Results obtained showed that the macaroni made of 25% sorghum flour and 75% wheat flour was still well accepted. Data from the analyses of solid loss, weight after cooking and volume increased of the macaroni indicated that the qualities of the sorghum macaroni met the local macaroni standard (Thai Industrial Standard Institute). The color of sorghum macaroni was darker than wheat macaroni and the optimum temperature for drying was 50-55 °C (83).

In 1997, Loahavaleesant formulated dietary fiber-enriched wheat noodles containing soybean hulls. The maximum soybean hulls quantity which could be substituted for wheat flour was 30%. Functional additives were also required to improve the noodle qualities such as xanthan gum and gluten. Sensory evaluation showed that the overall acceptability appeared between like slightly and like moderately.
and appearance were slightly hard and slightly brittle and darker than control formula (60).

Furthermore in 1998, Gomolmance studied supplementary use of dietary fiber in noodle products such as alkaline noodle, rice noodle and mungbean starch noodle. Wheat flour noodles was substituted with microcrystalline cellulose (MCC) and resistant starch (RS) at 7.5 and 1.5%, respectively. Rice noodle was substituted with 10% MCC and 15% RS. Mungbean starch noodle was substituted with 10% MCC and 20% RS. These substituted formulas were accepted by sensory test with no significant differences (p > 0.05) (61).

Due to very high consumption of instant noodles, which have low amount of DF, and mostly previous researches had supplemented DF in fresh noodles, without considering an appropriate ratio of IDF to SDF, instant noodles should be developed with high TDF content and well-balanced proportion of IDF and SDF.
CHAPTER III
MATERIALS AND METHODS

3.1 Materials and instruments

3.1.1 Materials for instant noodles preparation

- Wheat flour
  : all purpose flour, Kite brand (from United Flour Mill Public Co., Ltd.)

- Starch
  : Native potato starch, Modified potato starch (Perfectamyl AC.)
  (from Winner Group Enterprise Ltd.)
  : Modified tapioca starch A and B (from Siam Modified Starch Co., Ltd.)

- Guar gum (from Thai Food and Chemical Co., Ltd.)

- Sodium tripolyphosphate (STPP) (from Thai Food and Chemical Co., Ltd.)

- Sodium carbonate (from Grand Chemical Co., Ltd.)

- Potassium carbonate (from Grand Chemical Co., Ltd.)

- Salt : Prungthip brand (from Saha Pathanapibul Public Co., Ltd.)

- Vital wheat gluten 75 % (from Nutrition Ltd., Part.)

- Dietary fiber
  : SBH was provided by Green Spot (Thailand) Co., Ltd.
  : Carrageenan (CG), sodium carboxymethylcellulose (CMC) and
    konjac powder (KJ) (from Thai Food and Chemical Co., Ltd.)

- Palm oil; Emerald brand (from Morakot Industries Public Co., Ltd.)
- Seasoning powder: pork flavor (NST Food Ingredients Ltd and Thai President Foods Public Co., Ltd.)

3.1.2 Chemicals for analysis

- Enzyme assay kit for TDF, IDF and SDF analysis, Megazyme®, consisted of termamyl, protease and amyloglucosidase. This enzyme assay kit was purchased from Megazyme International (Ireland) Limited.

3.1.3 Instruments for instant noodles preparation

- Kitchen aid food mixer
- Noodle making machine ATLAS 150 (Marcato, Italy)
- Steamer
- Fryer

3.1.4 Instruments for SBH powder preparation

- Hammer mill
- Retsch Sieving Machine Type Vibro (HANN, W. Germany)

3.1.5 Instruments for physical analysis

- Spectrocolorimeter Model JS555 (Color Techno System Corporation, Japan)
- Texture Analyzer TA-xT2i (Stable Micro Systems, England)
3.2 Preparation of SBH powder

Contaminated materials such as leaf and stalk residues, pods, hilum, embryo, dust and stone were separated from SBH by manually sieving and air blowing. Then, the SBH were ground into powder by hammer mill attached with a 40 mesh (0.29 mm.) screen. The milled SBH was size separated on the Retch Sieving Machine Type Vibro and was shaken on a set of test sieves containing 60 and 100 mesh size screens for 30 min. The particles which passed through the 100 mesh sieve were used in this study (60). Figure 1 shows preparation of SBH powder. Figure 2 shows SBH and SBH powder.

![Diagram](attachment:image.png)

**Figure 1** Preparation of SBH powder
3.3 Preliminary formulation trial

3.3.1 Process adjustment and selection of the control formula

The instant noodle formulas used in this study were applied and chosen from basic formula of Taeteang's study (84) and Asian Noodles Training Course Workshop, Singapore (70).

The basic formula of Taeteang's study was modified by removing fresh egg from the formula for easier handling of the process. Ingredients i.e. sodium carbonate and sodium hydrogen carbonate were dissolved in water. Powder forms of guar gum, salt, sodium acid pyrophosphate (SAPP) and sodium tripolyphosphate (STPP) were together mixed on a magnetic stirrer. The mixing continued for at least 20 min or until guar gum became completely swollen (84). The mixture was then mixed with wheat flour in a kitchen aid mixer for 5-10 min. The dough was pressed in the plastic bag to form a rectangular block. Then, the dough were rested for 15 min. The dough sheeted by passing through a pair of rollers with a gap of 3.0 mm; and later 1.2 mm for six
steps. After that, the dough sheet was cut into threads in a noodle slitter to obtain a fresh noodle strips. Then, they were steamed and fried following the adjusted process.

### 3.3.1.1 Process adjustment

**a. Adjustment of steaming time**

Fresh noodles were steamed at various the steaming time to 8, 10 and 12 min. Then, the fifty grams of the steamed noodles were showered with soup (water 900 g, salt 60 g, MSG 20 g) and drained prior to placing in a drilled stainless steel mold. The noodles were deep-fried in palm oil at 160 °C until well cooked (1 min 40 sec to 1 min 45 sec). The fried noodles were removed from the mold, oil drained on a stainless steel screen and cooled down with an electric fan before packing in an aluminum foil bag. These instant noodles were tested to select the suitable steaming time by observation and eating quality determination.

**b. Adjustment of frying temperature**

The noodles were prepared by using the same formula. In case of process, the noodles were prepared in the same method by using the selected steaming time, but varying frying temperature to be at 160°C for 1 min 40 sec to 1 min 45 sec and 170°C for 1 min 10 sec to 1 min 15 sec. These instant noodles were tested to select suitable frying temperature by observation and eating quality determination.

Optimum steaming time and frying temperature were selected for instant noodle preparation in this study. The appropriate condition used in this study is show in Figure 3.
Alkaline solution
(Na$_2$CO$_3$ 0.1%, K$_2$CO$_3$ 0.1%)

Mixing guar gum, salt and polyphosphate
Together and dissolving in alkaline solution
for 20 min or until guar gum swell completely

Wheat flour
(starch, fiber and gluten)

Mixing (5-10 min)
Resting (15 min)
Sheeting (thickness 1.2 mm.)
Cutting
Steaming 100°C, 10 min
Showering with soup and draining
Frying 170°C,
1 min 10 sec to 1 min 15 sec

Figure 3 Diagram of instant noodles preparation
3.3.1.2 Selection of the control formula

According to the Asian Noodles Training Course Workshop's formula (70), guar gum in the formula was varied at 0.1, 0.3, 0.5, 0.7 and 1%. Additional amount of water was needed to complete guar gum swelling. The instant noodles were prepared by using the selected steaming time and frying temperature as diagram in Figure 3. These formulas were then tested to determine the suitable level of guar gum. After that, the formulas with optimum guar gum levels were evaluated noodle quality and sensory acceptability with the basic formula of Taeteang's study in order to use select a control formula.

3.3.1.3 Noodle quality evaluation

The noodles were evaluated for the quality in terms of appearance, cooking time and eating quality (67).

a. Appearance: The appearance was determined by visual observation of noodle color, surface and shape.

b. Cooking time: Noodles were cooked in a volume of water which was about ten times their weight. Twenty grams of instant noodles were cooked in 200 ml of boiling water. Instant noodles can be cooked to optimum cooking time or when the uncooked central core has just disappeared.

c. Eating quality: After cooking, the noodles were drained and placed in a stainless steel trays laid over crushed ice in order to minimize overcooking of the noodles. The weight of noodles were 15 g. Pork flavored soup was added prior to tasting. Subjects rated for eating quality which emphasize on potential problem characteristic i.e. grittiness, texture of the noodles
3.3.1.4 Sensory evaluation

The purpose of this part was to identify an optimum basic formula to select as a control formula using sensory evaluation for formula screening.

Acceptability of the control instant noodles was evaluated by twenty panelists who were recruited from staff and graduate students of Institute of Nutrition, Mahidol University. The experiment was designed as completely randomized block (85).

The instant noodles were cooked in boiling water, then immediately cooled down on a stainless steel tray laid over crushed ice in order to minimize overcooking of the noodles. The pork flavored soup was separately cooked and transferred into a double boiler, in order to maintain a constant temperature. Fifteen grams of the noodles were portioned into a white melamine bowl diameter 3.5 " labeled with three digit number codes selected from a random number table and then one-fourth cup of the hot soup was added before serving. The equilibrium temperature was about 50 °C, which was a serving temperature. All samples were served to each panelist during the test, however, only one sample was evaluated at a time. The order of sample presentation for a panelist was randomized. Panelist was asked to rinse his/her mouth with water between samples. The sensory evaluation was performed in Food Science and Technology Laboratory under daylight fluorescent bulb, air-conditioned and free from cooking odor and noise. The panelists were not allowed to communicate with each other.

Sensory acceptability of each sample was evaluated for general appearance, color suitability, overall acceptability, elasticity suitability and softness suitability. The overall acceptability and general appearance were determined on 9-
point hedonic scales. The scale ranged from “dislike extremely = 1” to “neither like nor dislike = 5” to “like extremely = 9”. Other characteristics were determined by five-point just-about-right scales. The scale ranged from “much too elastic / hard / dark = 5” to “just-about-right = 3” to “much too brittle / soft / light = 1”. The questionnaires used in the sensory test appear as Appendix A. A sample with the highest overall acceptability would be selected for using as a control formula.

3.3.2 Adjustment of the control formula

3.3.2.1 Selection of starch type and level of addition

Starch can produce short cooking time and good texture tolerance to overcooking. Therefore, the control formula was improved in the quality by partial substitution of wheat flour with starch. A part of flour was replaced by two types of starch that were potato starch i.e. native potato starch, modified potato starch (Perfectamyl AC.) and tapioca starch i.e. modified tapioca starch A and B. The substituted levels of potato starch were 5, 10 and 15% whereas the substituted levels of tapioca starch were 5, 7.5, and 10% according to the recommended usage.

3.3.2.2 Noodle quality evaluation

Noodle quality evaluation was the same as the one described used in section 3.3.1.3 in terms of appearance, cooking time and eating quality. In addition, the noodles were cooked until the texture appeared mushy in order to compare tolerance of each starch to overcooking effect.

3.3.2.3 Sensory evaluation

The sensory screening test was the same as those used in section 3.3.1.4
3.3.3 Formulation of DF-enriched instant noodles

Control and DF-enriched formulas of instant noodles were prepared following the diagram in Figure 3. SBH was used as the DF source in DF-enriched formulas by partial substitution for mixed flour. The flour was replaced with SBH starting at 15%. An additional amount of water was also needed to prevent drying out of the mix. These formulas were then tested to determine the highest substitution level that consumers can accept by sensory evaluation.

3.4 Formula adjustment of DF-enriched instant noodles

3.4.1 Effect of gluten

Gluten was added to improve the elasticity of noodles. The amount of gluten used in DF-enriched instant noodle formula started from minimum level and then adjusted until the samples were acceptable in general appearance and texture. Additional amount of water was also needed to develop gluten network. The amount of gluten, which gave the most suitable quality, was selected for formulating DF-enriched instant noodles and the noodles were tested for noodle quality and sensory acceptability. The amount of gluten used in DF-enriched noodle formula is shown in Appendix B.

3.4.2 Noodle quality evaluation

Noodle quality evaluation was performed in terms of appearance, cooking time and eating quality.
3.4.3 Sensory evaluation

Sensory evaluation for formula screening was performed on the DF-enriched noodles. The acceptable formulas would be selected for further study in an in-house consumer test.

In-house consumer test

In this part, sensory evaluation of instant noodles was made with a highest possible level of SBH which could be accepted by panelists in sensory evaluation for formula screening.

Fifty panelists included staff and graduate students of Institute of Nutrition, Mahidol University. The experimental design and all evaluating techniques were the same as the evaluation performed in sensory evaluation for formula screening. The finished products accepted by panelists in the in-house consumer test should have the overall acceptability scores over 6.

3.4.4 Physical analysis

DF-enriched instant noodles were determined for their physical characteristics in terms of color and texture profile analysis (TPA) measurement.

3.4.4.1 Color measurement

The color of the noodle doughs stored 15 min after sheeted was measured using a spectrocolorimeter Model JS 555. L*, a* and b* values were recorded. L* value indicates lightness; a* value indicates redness; b* value indicates yellowness of noodle dough sheets. Three replicates for each sample were determined. Measurement was made 3 times, each at a different location on the consistent (same) side of the surface of the noodle sheet (80, 86, 87).
3.4.4.2 TPA measurement

The texture properties were measured with a texture analyzer, TA-xT2i. Triplicates of cooked noodles were prepared. Five strands of cooked noodles were placed parallel on a flat metal plate and compressed twice to 75% of the noodle height with a cylinder probe P100. From the force-time curve of the TPA, hardness (height of the peak) and springiness (ratio between recovered height after first compression and the noodle height) of the noodles were determined. Adhesiveness is the negative area between the first and the second peak. Cohesiveness is the ratio between the area under the second peak and the area under the first peak; gumminess is the product of hardness and cohesiveness; chewiness is the product of gumminess and springiness that were obtained by automatic calculation from TPA curve (Appendix C). Tensile strengths were also determined. One cooked noodle strand was clamped by two lobes (A/SPR probe), and increasing tensile load was applied until breakage occurred. Tensile forces at break and break length were recorded (80, 86, 87). Triplicates were measured.

3.5 Adjustment of ratio of IDF and SDF in DF-enriched instant noodles

3.5.1 Adjustment of the ratio of IDF and SDF to be 2 and 1

SDF namely, carrageenan, CMC and konjac powder were selected to add in SBH-enriched instant noodle formula from the former part with the calculated level that provided the ratio of IDF and SDF to be 2 and 1.
3.5.2 Noodle quality evaluation

Noodle quality was determined in terms of appearance, cooking time and eating quality.

3.5.3 Sensory evaluation

The experimental design and technique were the same as the evaluation performed in section 3.4.3.

3.5.4 Physical analysis

Instant noodles with a well balanced ratio of IDF and SDF were determined for their physical characteristics in terms of color and texture profile analysis (TPA) measurement as described in section 3.4.4 compared with the optimum level of SBH-enriched instant noodles from the earlier trial.

3.6 Chemical analysis

The IDF and SDF-enriched products, which were selected from in-house consumer test, were also subjected to chemical analysis compared with the SBH-enriched formula and control.

3.6.1 Proximate analysis

Proximate analysis included crude protein (N×5.7), crude fat, ash, moisture, and carbohydrate contents. The analytical procedures were performed in duplicates according to the AOAC methods.

- Crude protein was determined by using the Macro-kjeldahl technique (88, 89).
- Crude fat was determined by solvent extraction in a Soxhlet apparatus (continuous extraction method using Soxtect System HT6, Tecator, Sweden) (89, 90).
- Ash was determined by incinerating a sample in a muffle furnace at 550°C (89).
- Moisture content of samples was determined by drying samples in a hot air oven at 105°C (89, 90).
- Carbohydrate content was calculated by subtracting the percentage of crude protein, fat, ash, moisture, and TDF from 100.
- Energy content factors 4, 4, and 9 were used to calculate the energy provided by protein, carbohydrate, and fat, respectively.

3.6.2 DF analysis
IDF, SDF and TDF were determined by the enzymatic-gravimetric method of modified AOAC (1990) method (91). The procedure is given as Appendix D.

3.7 Cost estimation of products
The cost of products were calculated based on raw materials only.

3.8 Statistical analysis
Data for physical properties of products were analyzed by Nonparametric Tests with SPSS for WINDOWS version 9.0 software. Significance among means was assessed by the Mann-Whitney U test at the 5% level of probability. In the part of sensory evaluation, mean values of the sensory acceptability scores of each product were evaluated for significant difference at 5% level of probability by using Mann-
Whitney U test or one-way analysis of variance (one-way ANOVA). When significant differences in one-way ANOVA were detected, means were compared using the Scheffe’s multiple comparison test (85).

The experimental schematic is shown in Figure 4.
Preliminary trial

Process adjustment
Selection of control formula
Adjustment of control formula

Control formula

Noodle quality evaluation
- Appearance
- Cooking time
- Eating quality

Acceptability test
- Sensory evaluation
(formula screening test)

Physical analysis
- TPA and tensile strength measurement

Nutritive value analysis
- Proximate analysis
- TDF, IDF, SDF analysis
- Color measurement

Formulation of DF-enriched product

Developed DF-enriched product

Noodle quality evaluation
- Appearance
- Cooking time
- Eating quality

Acceptability test
- Sensory evaluation
(formula screening and in-house consumer test)

Physical analysis
- TPA and tensile strength measurement

Nutritive value analysis
- Proximate analysis
- TDF, IDF, SDF analysis
- Color measurement

Adjustment of ratio of IDF and SDF for DF-enriched product

Noodle quality evaluation
- Appearance
- Cooking time
- Eating quality

Acceptability test
- Sensory evaluation
(formula screening and in-house consumer test)

Physical analysis
- TPA and tensile strength measurement

Nutritive value analysis
- Proximate analysis
- TDF, IDF, SDF analysis
- Color measurement

Figure 4 Experimental schematic
CHAPTER IV

RESULTS

4.1 Preliminary formulation trial

4.1.1 Process adjustment and selection of the control formula

During the first stage of the study, attempts were made to determine the basic instant noodle formula and process condition for using as the control formula.

4.1.1.1 Process adjustment

a. Adjustment of steaming time

As a result of appearance and eating quality, there was no difference among steaming time at 10 and 12 min whereas steaming time at 8 min gave incompletely gelatinized. Therefore, the steaming time at 10 min was chosen for the steaming step in order to save the time and cost of cooking.

b. Adjustment of frying temperature

In term of the frying temperature, the noodle fried at 170 °C gave yellow color whereas the noodles fried at 160 °C gave white-cream color. Thus, the frying temperature at 170 °C was selected for the instant noodle production because it is desirable to have yellow in instant noodle products (67, 92).

4.1.1.2 Selection of the control formula

The noodle formula with 0.7 and 1 % guar gum attained more desirable quality than the products with other guar gum levels. Thus, these formulas were chosen for noodle
quality and sensory evaluation compared with the modified (no egg) Taeteang’s basic formula.

4.1.1.3 Noodle quality evaluation

Table 8 Noodle quality of preliminary trial for control instant noodles

<table>
<thead>
<tr>
<th>Formula</th>
<th>Cooking time (min)</th>
<th>Appearance</th>
<th>Eating quality</th>
<th>Ease of processing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modified Taeteang’s basic formula</td>
<td>5</td>
<td>Yellow color - Had blister on the surface of fried noodle strands - Symmetrical shape</td>
<td>Elastic and soft texture</td>
<td>Too moist dough, hard to manage in sheeting and cutting steps</td>
</tr>
<tr>
<td>Instant noodles with 0.7% guar gum</td>
<td>6</td>
<td>Yellow color - Free from discoloration - Symmetrical shape</td>
<td>Elastic and moderately soft texture</td>
<td>Easy to process</td>
</tr>
<tr>
<td>Instant noodles with 1% guar gum</td>
<td>6</td>
<td>Yellow color - Free from discoloration - Symmetrical shape</td>
<td>Hard and chewy texture</td>
<td>Easy to process</td>
</tr>
</tbody>
</table>

From Table 8, the appearance of instant noodles with 0.7% and 1% guar gum (6 min of cooking time) were good quality whereas the appearance of noodles from Taeteang’s formula (5 min of cooking time) was poor. The eating quality of instant noodles with 0.7% guar gum was quite soft and suitable elastic compared with instant noodles with 1% guar gum. Moreover, instant noodles with 0.7% and 1% guar gum were easier to handle in sheeting and cutting process than noodles from modified Taeteang’s formula.
4.1.1.4 Sensory evaluation

Table 9 Sensory evaluation for formula screening $^{1,2}$ of preliminary trial for control instant noodles

<table>
<thead>
<tr>
<th>Formula</th>
<th>Before tasting</th>
<th>After tasting</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>General$^3$ appearance</td>
<td>Color$^3$ suitability</td>
</tr>
<tr>
<td>Modified</td>
<td>6.00 (0.94)</td>
<td>3.21$^a$ (0.54)</td>
</tr>
<tr>
<td>Taeteang’s basic formula</td>
<td>6.47 (0.84)</td>
<td>3.05$^{ab}$ (0.40)</td>
</tr>
<tr>
<td>Instant noodles with 0.7% guar gum</td>
<td>6.05 (1.08)</td>
<td>2.79$^a$ (0.54)</td>
</tr>
</tbody>
</table>

$^1$Mean (SD) from CRB design, n=20
$^2$Means with the same or without superscripts in a column are not significantly different (p>0.05)
$^3$Nine-point hedonic scale (9=like extremely, 5=neither like nor dislike, 1=dislike extremely)
$^4$Five-point just-about-right scale (5=much too elastic/hard/dark, 3=just about right, 1=much too brittle/soft/light

As a result in Table 9, the acceptability scores of general appearance, overall acceptability and elasticity suitability showed no significant difference (p>0.05) among all samples. The color and elasticity scores of instant noodles with 0.7% guar gum were closer to 3 than the other formulas whereas the overall acceptability and softness suitability score were moderately acceptable.

According to the good appearance, easy handling and acceptable sensory scores of instant noodles with 0.7% guar gum, this formula was selected as the control formula in further study.
4.1.2 Adjustment of the control formula

4.1.2.1 Selection of starch type and level of addition

Potato starch and tapioca starch were chosen for partial flour substitution in this part. The suitable type and optimum substituted level of each starch; which were 10% modified tapioca starch A and 15% modified potato starch (Perfectamyl AC.), were selected for evaluate noodle quality and sensory acceptability compared with the initial control formula. These two formulas were observed to be better than the remaining formulas in terms of cooking time and eating quality.

4.1.2.2 Noodle quality evaluation

Table 10 Noodle quality for adjustment of control instant noodles

<table>
<thead>
<tr>
<th>Formula</th>
<th>Cooking time (min)</th>
<th>Over cooking time (min)</th>
<th>Appearance</th>
<th>Eating quality</th>
<th>Ease of processing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial control formula</td>
<td>6</td>
<td>9</td>
<td>Yellow color</td>
<td>Elastic but harder than every formulas</td>
<td>Easy to process</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Free from discoloration</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Symmetrical shape</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial control with 10% modified tapioca starch A substitution</td>
<td>5</td>
<td>13</td>
<td>Yellow color</td>
<td>Slightly elastic and soft texture</td>
<td>Easy to process</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Free from discoloration</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Symmetrical shape</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial control with 15% modified potato starch substitution</td>
<td>3</td>
<td>13</td>
<td>Yellow color</td>
<td>Elastic, smooth, balance of softness and hardness in texture</td>
<td>Easy to process</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Free from discoloration</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Symmetrical shape</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 10 shows that all formulas were similar in appearance. Both of modified starches could reduce cooking time. Instant noodles with 15% modified potato starch substitution presented the least cooking time and best eating quality. All formulas were easy to process.
Table 11 Sensory evaluation for formula screening\textsuperscript{1,2} of adjustment of control instant noodles

<table>
<thead>
<tr>
<th>Formula</th>
<th>Before tasting</th>
<th>After tasting</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>General\textsuperscript{3} appearance</td>
<td>Color\textsuperscript{3} suitability</td>
</tr>
<tr>
<td>Initial control formula</td>
<td>6.25 (1.52)</td>
<td>3.25 (0.44)</td>
</tr>
<tr>
<td>Initial control with 10% modified tapioca starch A substitution</td>
<td>6.50 (1.43)</td>
<td>3.10 (1.29)</td>
</tr>
<tr>
<td>Initial control with 15% modified potato starch substitution</td>
<td>6.45 (1.50)</td>
<td>2.74 (0.55)</td>
</tr>
</tbody>
</table>

\textsuperscript{1}Mean (SD) from CRB design, n=20
\textsuperscript{2}Means with the same or without superscripts in a column are not significantly different (p>0.05)
\textsuperscript{3}Nine-point hedonic scale (9=like extremely, 5=neither like nor dislike, 1=dislike extremely)
\textsuperscript{4}Five-point just-about-right scale (5=much too elastic/hard/dark, 3=just-about-right, 1=much too brittle/soft/light)

According to Table 11, there was no significant difference (p>0.05) among all formulas in terms of general appearance, color, elasticity and softness. Overall acceptability score of instant noodles with 10% modified tapioca starch A substitution and 15% modified potato starch substitution were significantly higher than that of the control (p<0.05).

Consequently, in terms of good noodle quality, high overall acceptability score and less cooking time, instant noodles with 15% modified potato starch substitution gave better results than the initial control and the formula with 10% of modified tapioca starch A. Hence, it was selected as control in further study. This control formula is shown in Appendix B. Photographs of the control instant noodles are shown in Figure 5.
Figure 5 Uncooked (top) and cooked (bottom) control instant noodles
4.1.3 Formulation of DF-enriched instant noodles

As the amount of SBH increased, the poor quality products were obtained. The products were found to be gritty and rough. The color also became darker as DF level increased when compared with the control instant noodles. When SBH was used to substitute more than 40% of flour, the noodle dough became crumbly, rough surface and the noodle sheet could not be cut into strips. Consequently, the selected levels of SBH for using in the DF-enriched instant noodles were 15%, 20%, 25%, 30%, 35% and 40% mixed flour substitution.

4.2 Formula adjustment of DF-enriched instant noodles

4.2.1. Effect of gluten

Firstly, the instant noodles with 30, 35 and 40% SBH substitution were chosen to adjust the amount of gluten in order to maximize the highest possible DF substituted level. Different amount of gluten was added to DF-enriched instant noodle formulas to determine the optimum amount of gluten for each formula. The suitable amount of gluten for 30, 35 and 40% SBH substitution was 30% by weight. Gluten level in excess of 30% presented difficulties in dough sheeting process. The noodle quality and sensory screening data are shown in Table 12 and 13, respectively.
Table 12 Noodle quality evaluation of 30, 35 and 40% SBH-enriched instant noodles with gluten.

<table>
<thead>
<tr>
<th>Formula</th>
<th>Cooking time (min)</th>
<th>Appearance</th>
<th>Eating quality</th>
<th>Ease of processing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instant noodles with 30% SBH substitution</td>
<td>3.5</td>
<td>Brown color - Symmetrical shape</td>
<td>Gritty mouthfeel - Rough and hard texture</td>
<td>Easy to process</td>
</tr>
<tr>
<td>Instant noodles with 35% SBH substitution</td>
<td>3.5</td>
<td>Darker brown color - Symmetrical shape</td>
<td>Grittier mouthfeel - Rough and hard texture</td>
<td>Easy to process</td>
</tr>
<tr>
<td>Instant noodles with 40% SBH substitution</td>
<td>3.5</td>
<td>Very dark brown color - Symmetrical shape</td>
<td>Grittiest mouthfeel - Very rough and hard texture</td>
<td>Easy to process</td>
</tr>
</tbody>
</table>

Table 13 Sensory evaluation for formula screening of 30, 35 and 40% SBH-enriched instant noodles with gluten.

<table>
<thead>
<tr>
<th>Formula</th>
<th>Before tasting</th>
<th>After tasting</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>General(^a)</td>
<td>Color(^b)</td>
</tr>
<tr>
<td></td>
<td>appearance</td>
<td>suitability</td>
</tr>
<tr>
<td>Instant noodles with 30% SBH substitution</td>
<td>5.65 (1.27)</td>
<td>3.80 (0.70)</td>
</tr>
<tr>
<td>Instant noodles with 35% SBH substitution</td>
<td>5.10 (1.25)</td>
<td>4.30 (0.66)</td>
</tr>
<tr>
<td>Instant noodles with 40% SBH substitution</td>
<td>4.80 (1.44)</td>
<td>4.35 (0.67)</td>
</tr>
</tbody>
</table>

\(^a\)Mean (SD) from CRB design, n=20
\(^b\)Means with the same or without superscripts in a column are not significantly different (p > 0.05)
\(^c\)Nine-point hedonic scale (9=like extremely, 5=neither like nor dislike, 1=dislike extremely)
\(^d\)Five-point just-about-right scale (5=much too elastic/hard/dark, 3=just-about-right, 1=much too brittle/soft/light

From the results in the Table 12, cooking time of all formulas was 3 min 30 sec. Although 30% gluten could improve on dough sheeting step, the consumers could
not accept the gritty texture of the finished products. According to the sensory evaluation results, overall acceptability score of 35 and 40% SBH substitution instant noodles were about 4 which means that these formulas were rated as “dislike slightly” whereas the 30% SBH substitution formula was judged as “neither like nor dislike”. Therefore, in the subsequent formulation of the product, lower levels of substitution would be employed.

Different amount of gluten was added to 15, 20 and 25% SBH-enriched instant noodle formulas in order to determine the optimum amount of gluten. The suitable amount of gluten for 15, 20 and 25% SBH substitution were 20, 25 and 30% by weight, respectively. The noodle quality data are shown in Table 14.

Table 14 Noodle quality evaluation of 15, 20 and 25 % SBH-enriched instant noodles with gluten.

<table>
<thead>
<tr>
<th>Formula</th>
<th>Cooking time (min)</th>
<th>Appearance</th>
<th>Eating quality</th>
<th>Ease of processing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instant noodles with 15% SBH substitution</td>
<td>3</td>
<td>Light brown color</td>
<td>Slightly gritty mouthfeel</td>
<td>Easy to process</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Symmetrical shape</td>
<td>Slightly rough texture</td>
<td></td>
</tr>
<tr>
<td>Instant noodles with 20% SBH substitution</td>
<td>3</td>
<td>Brown in color</td>
<td>Grittier mouthfeel</td>
<td>Easy to process</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Symmetrical shape</td>
<td>Rough texture</td>
<td></td>
</tr>
<tr>
<td>Instant noodles with 25% SBH substitution</td>
<td>3</td>
<td>Darker brown color</td>
<td>Grittiest mouthfeel</td>
<td>Easy to process</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Symmetrical shape</td>
<td>Rough texture</td>
<td></td>
</tr>
</tbody>
</table>

Table 14 shows the better eating quality with decreased mixed flour substitution level with SBH. In addition, Figure 6 shows instant noodles substituted with 15, 20 and 25% SBH compared with control.
Figure 6  Uncooked (top) and cooked (bottom) instant noodles substituted with 15, 20 and 25% SBH compared with control.
4.2.2 Sensory evaluation

Table 15  Sensory evaluation for formula screening\(^1,2\) of 15, 20 and 25 % SBH-enriched instant noodles with gluten.

<table>
<thead>
<tr>
<th>Formula</th>
<th>Before tasting</th>
<th>After tasting</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>General(^3)</td>
<td>Color(^4)</td>
</tr>
<tr>
<td>Instant noodles with</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15% SBH substitution</td>
<td>6.75(^a) (0.85)</td>
<td>3.15(^c) (0.49)</td>
</tr>
<tr>
<td>Instant noodles with</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20% SBH substitution</td>
<td>5.85(^b) (1.04)</td>
<td>3.80(^b) (0.52)</td>
</tr>
<tr>
<td>Instant noodles with</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25% SBH substitution</td>
<td>5.35(^b) (1.42)</td>
<td>4.30(^a) (0.47)</td>
</tr>
</tbody>
</table>

\(^1\)Mean (SD) from CRB design, n=20
\(^2\)Means with the same or without superscripts in a column are not significantly different (p>0.05)
\(^3\)Nine-point hedonic scale (9=like extremely, 5=neither like nor dislike, 1=dislike extremely)
\(^4\)Five-point just-about-right scale (5=much too elastic/hard/dark, 3=just-about-right, 1=much too brittle/soft/light

No significant differences (p>0.05) were found for the overall acceptability, elasticity and softness suitability among all samples. Nevertheless, the DF-enriched instant noodles with 15% SBH gave significantly suitable color than the other levels of SBH-enriched instant noodles which resulted in significantly highest score in general appearance. The overall acceptability score of every formula exceeded 5, meaning "like slightly" or more. Therefore, an in-house consumer test was carried out to confirm this observation. The results are shown in Table 16.
### Table 16 In-house consumer test of 15, 20 and 25 % SBH-enriched instant noodles with gluten.\(^1,2\)

<table>
<thead>
<tr>
<th>Formula</th>
<th>Before tasting</th>
<th>After tasting</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>General(^5) Appearance</td>
<td>Color(^4) suitability</td>
</tr>
<tr>
<td>Instant noodles with 15% SBH substitution</td>
<td>5.78 (1.23)</td>
<td>3.60(^b) (0.61)</td>
</tr>
<tr>
<td>Instant noodles with 20% SBH substitution</td>
<td>5.36 (1.38)</td>
<td>3.80(^{ab}) (0.70)</td>
</tr>
<tr>
<td>Instant noodles with 25% SBH substitution</td>
<td>5.14 (1.46)</td>
<td>4.12(^a) (0.69)</td>
</tr>
</tbody>
</table>

\(^1\)Mean (SD) from CRB design, n=50  
\(^2\)Means with the same or without superscripts in a column are not significantly different (p>0.05)  
\(^3\)Nine-point hedonic scale (9=like extremely, 5=neither like nor dislike, 1=dislike extremely)  
\(^4\)Five-point just-about-right scale (5=much too elastic/hard/dark, 3=just-about-right, 1=much too brittle/soft/light

There were significant differences (p<0.05) among the formulas in terms of color and softness suitability as well as overall acceptability whereas no significant differences were found (p>0.05) for appearance and elasticity. The overall acceptability score of DF-enriched instant noodles with 15% SBH was 6 from 9-point hedonic scale highest which means that this formula was liked slightly. Thus, this formula was selected for adjusting the ratio of IDF and SDF to be 2 and 1 as recommended.
4.2.3 Physical analysis

4.2.3.1 Color measurement

Table 17 Noodle dough sheet color of SBH-enriched instant noodles compared with control formula\textsuperscript{1,2}

<table>
<thead>
<tr>
<th>Formula</th>
<th>L\textsuperscript{*}</th>
<th>a\textsuperscript{*}</th>
<th>b\textsuperscript{*}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control formula</td>
<td>84.83\textsuperscript{a} (0.39)</td>
<td>-2.20\textsuperscript{c} (0.09)</td>
<td>14.42\textsuperscript{c} (0.71)</td>
</tr>
<tr>
<td>Instant noodles with 15% SBH substitution</td>
<td>64.39\textsuperscript{b} (0.38)</td>
<td>1.09\textsuperscript{b} (0.04)</td>
<td>20.73\textsuperscript{b} (0.06)</td>
</tr>
<tr>
<td>Instant noodles with 20% SBH substitution</td>
<td>62.67\textsuperscript{c} (0.20)</td>
<td>1.18\textsuperscript{b} (0.07)</td>
<td>20.96\textsuperscript{b} (0.04)</td>
</tr>
<tr>
<td>Instant noodles with 25% SBH substitution</td>
<td>60.59\textsuperscript{d} (0.39)</td>
<td>1.35\textsuperscript{a} (0.05)</td>
<td>21.16\textsuperscript{a} (0.07)</td>
</tr>
</tbody>
</table>

\textsuperscript{1}Results are means (SD) of triplicate analysis.
\textsuperscript{2}Means with the same or without superscripts in a column are not significantly different (p>0.05)

From Table 17, the level of mixed flour replacement by SBH in the instant noodle formula had an effect on L\textsuperscript{*} values (lightness) of noodle dough. When flour substitution level with SBH increased, L\textsuperscript{*} value of noodle dough decreased significantly (p<0.05). Moreover, incorporation of SBH affected the a\textsuperscript{*} value (redness) of SBH-enriched instant noodles. As the percentage of SBH increased, a consistent increase in a\textsuperscript{*} value of instant noodles occurred at all SBH substitution levels. In addition, the b\textsuperscript{*} value (yellowness) of noodle dough increased significantly (p<0.05) by SBH incorporation. Overall it was found that SBH-enriched instant noodles were darker in color than the control formula and the color intensity increased correspondingly with the level of SBH used.
### 4.2.3.2 TPA measurement

**Table 18** Texture profile analysis (TPA) of cooked SBH-enriched instant noodles compared with control formula

<table>
<thead>
<tr>
<th>Formula</th>
<th>Hd (g)</th>
<th>Ad (g)</th>
<th>Co Ratio</th>
<th>Sp Ratio</th>
<th>Gu (g)</th>
<th>Ch (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>14357.03&lt;sup&gt;b&lt;/sup&gt; (825.67)</td>
<td>116.46&lt;sup&gt;a&lt;/sup&gt; (1.20)</td>
<td>0.80 (0.01)</td>
<td>0.92 (0.01)</td>
<td>11532.40&lt;sup&gt;b&lt;/sup&gt; (661.08)</td>
<td>10657.06&lt;sup&gt;b&lt;/sup&gt; (542.84)</td>
</tr>
<tr>
<td>Instant noodles with 15% SBH substitution</td>
<td>16434.80&lt;sup&gt;a&lt;/sup&gt; (977.71)</td>
<td>56.21&lt;sup&gt;c&lt;/sup&gt; (1.43)</td>
<td>0.86 (0.01)</td>
<td>0.92 (0.02)</td>
<td>14193.90&lt;sup&gt;a&lt;/sup&gt; (1094.41)</td>
<td>13019.17&lt;sup&gt;a&lt;/sup&gt; (1019.64)</td>
</tr>
<tr>
<td>Instant noodles with 20% SBH substitution</td>
<td>15629.23&lt;sup&gt;a&lt;/sup&gt; (137.36)</td>
<td>73.83&lt;sup&gt;b&lt;/sup&gt; (0.83)</td>
<td>0.85 (0.01)</td>
<td>0.89 (0.04)</td>
<td>13249.64&lt;sup&gt;a&lt;/sup&gt; (351.09)</td>
<td>11742.85&lt;sup&gt;a&lt;/sup&gt; (372.54)</td>
</tr>
<tr>
<td>Instant noodles with 25% SBH substitution</td>
<td>14181.46&lt;sup&gt;b&lt;/sup&gt; (575.06)</td>
<td>71.50&lt;sup&gt;b&lt;/sup&gt; (4.29)</td>
<td>0.86 (0.02)</td>
<td>0.85 (0.07)</td>
<td>12135.19&lt;sup&gt;b&lt;/sup&gt; (709.41)</td>
<td>10220.41&lt;sup&gt;b&lt;/sup&gt; (273.50)</td>
</tr>
</tbody>
</table>

<sup>1</sup>Results are means (SD) of triplicate analysis.
<sup>2</sup>Means with the same or without superscripts in a column are not significantly different (p>0.05).
<sup>3</sup>Hd=hardness; Ad=adhesiveness; Co=cohesiveness; Sp=springiness; Gu=gumminess; Ch=chewiness

All TPA parameters (Table 18) of cooked control noodles except adhesiveness showed scores equal to or less than SBH substituted formulas. The SBH-enriched instant noodles yielded a decrease in hardness, gumminess and chewiness as the level of substitution with SBH increased. There were no significant differences (p>0.05) in cohesiveness and springiness among all formulas.
Table 19 Tensile strength and break length of SBH-enriched instant noodles compared with control formula

<table>
<thead>
<tr>
<th>Formula</th>
<th>Tensile strength (g)</th>
<th>Break length (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>18.70&lt;sup&gt;c&lt;/sup&gt;</td>
<td>40.37&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>(0.32)</td>
<td>(0.89)</td>
</tr>
<tr>
<td>Instant noodles with 15%</td>
<td>34.04&lt;sup&gt;a&lt;/sup&gt;</td>
<td>56.29&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>SBH substitution</td>
<td>(0.91)</td>
<td>(1.61)</td>
</tr>
<tr>
<td>Instant noodles with 20%</td>
<td>33.32&lt;sup&gt;a&lt;/sup&gt;</td>
<td>51.45&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>SBH substitution</td>
<td>(0.72)</td>
<td>(1.83)</td>
</tr>
<tr>
<td>Instant noodles with 25%</td>
<td>29.27&lt;sup&gt;b&lt;/sup&gt;</td>
<td>45.16&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>SBH substitution</td>
<td>(0.24)</td>
<td>(0.50)</td>
</tr>
</tbody>
</table>

<sup>1</sup>Results are means (SD) of triplicate analysis.
<sup>2</sup>Means with the same or without superscripts in a column are not significantly different (p>0.05)

Table 19 presents the results of tensile strength measurement for SBH-enriched instant noodles compared with control. SBH-enriched instant noodles showed higher tensile strength and breaking length than control formula. Tensile strength and breaking length decreased as the level of substitution with SBH increased.

4.3 Adjustment of ratio of IDF and SDF in DF-enriched instant noodles

From the results of SBH-substituted instant noodles part, 15% SBH level was selected to use as IDF source in this part. Amount of carrageenan (CG), CMC and konjac powder (KJ), SDF sources were adjusted to be approximately half of SBH level. The formulated instant noodles were evaluated for noodle quality and sensory acceptability.
4.3.1 Noodle quality evaluation

Table 20 Noodle quality of CG-SBH, CMC-SBH and KJ-SBH-enriched instant noodles

<table>
<thead>
<tr>
<th>Formula</th>
<th>Cooking time (min)</th>
<th>Appearance</th>
<th>Eating quality</th>
<th>Additional process and ingredients</th>
</tr>
</thead>
<tbody>
<tr>
<td>CG-SBH-enriched instant noodles</td>
<td>3</td>
<td>Light brown color</td>
<td>Very slightly gritty mouthfeel</td>
<td>CG was added and mixed with wheat flour in dry powder form</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Symmetrical shape</td>
<td>Soft and elastic texture</td>
<td>No additional water needed</td>
</tr>
<tr>
<td>CMC-SBH-enriched instant noodles</td>
<td>2.5</td>
<td>Light brown color</td>
<td>Very slightly gritty mouthfeel</td>
<td>CMC was added and mixed with wheat flour in dry powder form</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Symmetrical shape</td>
<td>Soft and elastic texture</td>
<td>Additional water was needed to prevent drying out of the mix</td>
</tr>
<tr>
<td>KJ-SBH-enriched instant noodles</td>
<td>3</td>
<td>Light brown color</td>
<td>Very slightly gritty mouthfeel</td>
<td>KJ was added and mixed with wheat flour in dry powder form</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Symmetrical shape</td>
<td>Soft and elastic texture</td>
<td>Additional water was needed to prevent drying out of the mix</td>
</tr>
</tbody>
</table>

All formulas showed light brown color and symmetrical shape. These formulas yielded better eating quality than SBH-enriched instant noodles from the earlier trial. CMC-SBH-enriched instant noodles gave the least cooking time. Figure 7 shows CG-SBH, CMC-SBH and KJ-SBH-enriched instant noodles compared with control.
Figure 7 Uncooked (top) and cooked (bottom) CG-SBH, CMC-SBH and KJ-SBH-enriched instant noodles compared with control.

(CG-SBH = CG+SBH, CMC-SBH = CG+SBH, KJ-SBH = KJ+SBH)
4.3.2 Sensory evaluation

CG-SBH, CMC-SBH and KJ-SBH enriched instant noodles exhibited better characteristics in appearance and eating quality than SBH-enriched formula. In-house consumer test were carried out to confirm these results. The sensory acceptability scores are shown in Table 21.

Table 21 In-house consumer test of CG-SBH, CMC-SBH and KJ-SBH-enriched instant noodles

<table>
<thead>
<tr>
<th>Formula</th>
<th>Before tasting</th>
<th>After tasting</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>General^3</td>
<td>Color^4</td>
</tr>
<tr>
<td></td>
<td>Appearance</td>
<td>suitability</td>
</tr>
<tr>
<td>CG-SBH-enriched instant noodles</td>
<td>6.06 (1.33)</td>
<td>3.54 (0.61)</td>
</tr>
<tr>
<td>CMC-SBH-enriched instant noodles</td>
<td>6.08 (1.29)</td>
<td>3.54 (0.73)</td>
</tr>
<tr>
<td>KJ-SBH-enriched instant noodles</td>
<td>5.66 (1.35)</td>
<td>3.68 (0.79)</td>
</tr>
</tbody>
</table>

^1Mean (SD) from CRB design, n=20
^2Means with the same or without superscripts in a column are not significantly different (p>0.05)
^3Nine-point hedonic scale (9=like extremely, 5=neither like nor dislike, 1=dislike extremely)
^4Five-point just-right-scale (5=much too elastic/hard/dark, 3=just-about-right, 1=much too brittle/soft/light

All formulas presented no significant differences (p>0.05) in terms of general appearance, color suitability, overall acceptability, elasticity suitability and softness suitability. Overall acceptability ranged from 5.74 to 6.18 of 9-point hedonic scale which means that these formulas were liked slightly.
4.3.3 Physical analysis

4.3.3.1 Color measurement

Table 22  Noodle dough sheet color of CG-SBH, CMC-SBH and KJ-SBH-enriched instant noodles compared with SBH-enriched instant noodles

<table>
<thead>
<tr>
<th>Formula</th>
<th>L*</th>
<th>a*</th>
<th>b*</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBH-enriched instant noodles</td>
<td>64.39</td>
<td>1.09</td>
<td>20.73</td>
</tr>
<tr>
<td></td>
<td>(0.38)</td>
<td>(0.04)</td>
<td>(0.06)</td>
</tr>
<tr>
<td>CG-SBH-enriched instant noodles</td>
<td>67.49</td>
<td>0.52</td>
<td>20.39</td>
</tr>
<tr>
<td></td>
<td>(0.24)</td>
<td>(0.02)</td>
<td>(0.11)</td>
</tr>
<tr>
<td>CMC-SBH-enriched instant noodles</td>
<td>68.37</td>
<td>0.29</td>
<td>19.73</td>
</tr>
<tr>
<td></td>
<td>(0.46)</td>
<td>(0.01)</td>
<td>(0.19)</td>
</tr>
<tr>
<td>KJ-SBH-enriched instant noodles</td>
<td>66.29</td>
<td>0.32</td>
<td>19.92</td>
</tr>
<tr>
<td></td>
<td>(0.41)</td>
<td>(0.02)</td>
<td>(0.03)</td>
</tr>
</tbody>
</table>

Results are means (SD) of triplicate analysis.

Means with the same or without superscripts in a column are not significantly different (p>0.05)

According to Table 22, CG-SBH, CMC-SBH and KJ-SBH-enriched instant noodles showed lighter color, i.e. higher L* value whereas a* value and b* value were significantly lower than those of SBH substituted instant noodles (p<0.05).
4.3.3.2 TPA measurement

Table 23 Texture profile analysis (TPA) of cooked CG-SBH, CMC-SBH and KJ-SBH-enriched instant noodles compared with SBH-enriched instant noodles

<table>
<thead>
<tr>
<th>Formula</th>
<th>Hd (g)</th>
<th>Ad (g)</th>
<th>Co Ratio</th>
<th>Sp Ratio</th>
<th>Gu (g)</th>
<th>Ch (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBH-enriched instant noodles</td>
<td>1643.80</td>
<td>56.21</td>
<td>0.85</td>
<td>0.92</td>
<td>1419.30</td>
<td>13019.17</td>
</tr>
<tr>
<td></td>
<td>(977.71)</td>
<td>(1.43)</td>
<td>(0.01)</td>
<td>(0.02)</td>
<td>(1094.41)</td>
<td>(1019.64)</td>
</tr>
<tr>
<td>CG-SBH-enriched instant noodles</td>
<td>20020.77</td>
<td>86.98</td>
<td>0.84</td>
<td>0.94</td>
<td>16845.55</td>
<td>15771.87</td>
</tr>
<tr>
<td></td>
<td>(562.64)</td>
<td>(2.57)</td>
<td>(0.01)</td>
<td>(0.02)</td>
<td>(557.69)</td>
<td>(545.45)</td>
</tr>
<tr>
<td>CMC-SBH-enriched instant noodles</td>
<td>1896.83</td>
<td>81.66</td>
<td>0.85</td>
<td>0.90</td>
<td>16138.05</td>
<td>14485.27</td>
</tr>
<tr>
<td></td>
<td>(478.99)</td>
<td>(3.92)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(341.53)</td>
<td>(296.22)</td>
</tr>
<tr>
<td>KJ-SBH-enriched instant noodles</td>
<td>1829.85</td>
<td>129.32</td>
<td>0.85</td>
<td>0.90</td>
<td>15603.50</td>
<td>13960.67</td>
</tr>
<tr>
<td></td>
<td>(129.66)</td>
<td>(19.57)</td>
<td>(0.01)</td>
<td>(0.02)</td>
<td>(67.44)</td>
<td>(398.01)</td>
</tr>
</tbody>
</table>

1Results are means (SD) of triplicate analysis.
2Means with the same or without superscripts in a column are not significantly different (p>0.05)
3Hd=hardness; Ad=adhesiveness; Co=cohesiveness; Sp=springiness; Gu=gumminess; Ch=chewiness

From Table 23, CG-SBH, CMC-SBH and KJ-SBH-enriched instant noodles showed significantly higher (p<0.05) hardness, adhesiveness, gumminess and chewiness scores than SBH-enriched instant noodles. Cohesiveness and springiness presented no significant difference (p>0.05) among all formulas.

Table 24 Tensile strength and break length of cooked CG-SBH, CMC-SBH and KJ-SBH-enriched instant noodles compared with SBH-enriched instant noodles

<table>
<thead>
<tr>
<th>Formula</th>
<th>Tensile strength (g)</th>
<th>Break length (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBH-enriched instant noodles</td>
<td>34.05 (0,91)</td>
<td>56.29 (1,61)</td>
</tr>
<tr>
<td>CG-SBH-enriched instant noodles</td>
<td>26.82 (0,19)</td>
<td>54.34 (5,51)</td>
</tr>
<tr>
<td>CMC-SBH-enriched instant noodles</td>
<td>31.80 (1,42)</td>
<td>55.45 (3,88)</td>
</tr>
<tr>
<td>KJ-SBH-enriched instant noodles</td>
<td>21.52 (1,29)</td>
<td>42.68 (1,26)</td>
</tr>
</tbody>
</table>

1Results are means (SD) of triplicate analysis.
2Means with the same or without superscripts in a column are not significantly different (p>0.05)
From Table 24, the values of tensile strength were significantly different (p<0.05) whereas breaking length showed no significant differences (p>0.05) among all instant noodle formulas.

4.4 Chemical Analysis

Proximate composition and DF content (TDF, IDF, SDF) of control, SBH-enriched instant noodles and CG-SBH-enriched instant noodles, which represented instant noodles with a well balanced ratio of IDF and SDF, are shown in Table 25. The CG-SBH-enriched instant noodles contained slightly higher ash content than the SBH-enriched instant noodles and control formula. On the other hand, the protein content of DF-enriched instant noodles were higher (about 2 times) than that of the control. Control and DF-enriched instant noodles contained similar fat content. DF-enriched instant noodles contained slightly higher moisture content than the control. As expected the DF-enriched instant noodles contained more TDF content and less carbohydrate and energy content (energy reduced 4.8 % for SBH-enriched instant noodles and 6.9 % for CG-SBH-enriched instant noodles) when compared with control formula. In addition, SBH-enriched instant noodles and CG-SBH-enriched instant noodles contained 4.3 times and 4.6 times the DF content of control instant noodles, respectively. Moreover, IDF and SDF ratio in CG-SBH-enriched instant noodle formula was 2 to 1 as expected by calculation during formula development.
Table 25 The nutrient composition of DF-enriched instant noodles compared to control instant noodles (per 100 g wet basis)$^1$

<table>
<thead>
<tr>
<th>Nutrient composition</th>
<th>Control formula</th>
<th>SBH-enriched instant noodles</th>
<th>CG-SBH-enriched instant noodles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture (g)</td>
<td>1.8</td>
<td>2.0</td>
<td>2.3</td>
</tr>
<tr>
<td>Fat (g)</td>
<td>19.2</td>
<td>21.0</td>
<td>20.7</td>
</tr>
<tr>
<td>Protein (g)</td>
<td>8.0</td>
<td>16.6</td>
<td>16.3</td>
</tr>
<tr>
<td>Ash (g)</td>
<td>4.9</td>
<td>4.7</td>
<td>5.7</td>
</tr>
<tr>
<td>Carbohydrate (g)</td>
<td>63.7</td>
<td>45.6</td>
<td>44.2</td>
</tr>
<tr>
<td>Energy (kcal)</td>
<td>459</td>
<td>437</td>
<td>428</td>
</tr>
<tr>
<td>TDF (g)</td>
<td>2.3</td>
<td>10.1</td>
<td>10.8</td>
</tr>
<tr>
<td>IDF (g)</td>
<td>1.5</td>
<td>8.0</td>
<td>6.8</td>
</tr>
<tr>
<td>SDF (g)</td>
<td>0.9</td>
<td>2.5</td>
<td>3.3</td>
</tr>
</tbody>
</table>

$^1$Results are means of duplicate analysis of one sample.

Table 26 shows the amount of TDF per serving (50 g) and % Thai RDI. One serving of SBH-enriched instant noodles and CG-SBH-enriched instant noodles contained 5.06 g and 5.40 g of TDF, respectively. These amount were equivalent to about 20% Thai RDI. Thus these products could be labeled as “high fiber product” according to the Ministry of Public Health the Notification no, 182 (B.E. 2541) on nutrition labeling.

Table 26 TDF content with percent Thai RDI of control and DF-enriched instant noodles (per serving)$^1$

<table>
<thead>
<tr>
<th>Formula</th>
<th>TDF (g)</th>
<th>%RDI$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>1.17</td>
<td>4.68</td>
</tr>
<tr>
<td>SBH-enriched instant noodles</td>
<td>5.06</td>
<td>20.24</td>
</tr>
<tr>
<td>CG-SBH-enriched instant noodles</td>
<td>5.40</td>
<td>21.60</td>
</tr>
</tbody>
</table>

$^1$One serving of instant noodles = 50 g

$^2$Percent RDI, based on 2,000 kcal diet
4.5 Cost of the products

The cost of DF-enriched instant noodles (calculated for fried noodle cake only, based on raw materials) was compared with control instant noodles and is shown in Table 27. The cost of 15% SBH-enriched instant noodles was similar to that of the control. The cost of CG-SBH, CMC-SBH and KJ-SBH-enriched instant noodles were higher than that of the control. These costs were based on the fact that no cost of SBH was charged in they were since they were by-product from soybean processing industry.

Table 27 Cost estimation of DF-enriched instant noodles compared to control formula (raw materials only)

<table>
<thead>
<tr>
<th>Product</th>
<th>Cost</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Baht/100 g product)</td>
<td>(Baht/serving)</td>
</tr>
<tr>
<td>Control instant noodles</td>
<td>4.56</td>
<td>2.28</td>
</tr>
<tr>
<td>SBH-enriched instant noodles</td>
<td>4.84</td>
<td>2.42</td>
</tr>
<tr>
<td>CG-SBH-enriched instant noodles</td>
<td>7.01</td>
<td>3.51</td>
</tr>
<tr>
<td>CMC-SBH-enriched instant noodles</td>
<td>6.09</td>
<td>3.05</td>
</tr>
<tr>
<td>KJ-SBH-enriched instant noodles</td>
<td>6.93</td>
<td>3.47</td>
</tr>
</tbody>
</table>
CHAPTER V
DISCUSSION

5.1 Preliminary formulation trial

5.1.1 Process adjustment and selection of the control formula

Generally, instant noodles are manufactured in a continuous line of an automated plant. Due to the limitation of available instruments in the laboratory such as pressure steamer and closed circulated fryer, the process must be adjusted especially condition of the steaming and frying steps. In addition, steaming and frying are important processes in instant noodle production. Steaming reduces the loss of solids and fixes the shape of a preformed serving whereas frying removes moisture from noodles and thereby fixes the structural form of the noodles (70).

Steaming time was varied at 8, 10 and 12 min due to the recommendation from the Asian Noodle Training Course (70) which suggested 8-10 min and Moss et al. (1987) inferred about 10 min (67). Eventually, ten min steaming turned out to be adequate for starch granules to become fully gelatinized.

Frying temperature at 170 °C was selected whereas the usual frying temperature in the plant was 160°C. The higher frying temperature for this study was due to the lower efficiency of fryer and frying in open system that may produce incompletely circulated heat transfer. In addition, the higher temperature seemed to be beneficial because it gave the shorter frying time which resulted in lower oil uptake. Kim and Lee (1990) reported that a high frying temperature increases uptake of oil
High uptake of oil during frying not only increases the cost of the finished product, but also can adversely affect shelf life.

After that, control formula was selected by assessing noodle quality in terms of appearance, cooking time and eating quality.

Appearance especially color is most important as it is the first quality parameter perceived by the consumer. Noodles should be yellow in color, free from discoloration and symmetrical in shape. In this study, the blisters on surface of the noodles made from modified Taeteang’s formula may be caused by too much moisture or the effect of sodium bicarbonate used in this formula.

Usually, instant noodles are cooked in boiling water for 3-4 min prior to assessment. The optimum cooking time would yield desirable texture. If noodles are overcooked, the starch granules near the surface gain too much water and become paste-like, resulting in loss of starch into cooking water, loss of firmness and increased stickiness.

Assessment of noodle quality is usually based on sensory evaluation. Commonly, instant noodles should have a firm and elastic texture and surface should not be sticky. Higher score in 9-point hedonic scales are allocated to noodles with a firm (not tough) texture, springy bite (elasticity) and smooth surface. The score around 3 in just-about-right scales are related to desirable color, elasticity and softness characteristics.

5.1.2 Adjustment of the control formula

The initial control formula from previous section was further developed by partial substitution of wheat flour by starch. As a result, the formula substituted with
starch presented the shorter cooking time and soft and elastic texture. Starch could be quickly gelatinized and maintained a high maximum viscosity that contributes to the texture (69, 94, 95, 96). The reasons for these results may be explained by experiment data of Seib, 1997 (100) and Ross et al., 1997 (97). They stated that starch granules near the surface swell to release more amylose between granules during cooking. Upon cooking, the amylose-rich phase between the gluten fibrils and starch granules forms a gel that imparts a smooth surface. Inside the noodle strand, the extra swelling of the starch causes more water to be imbibed, which increases noodle yield and gives a soft elastic bite. Consequently, 15 % modified potato starch was best accepted and selected for further formulation to incorporate DF source i.e. SBH.

5.2 Formulation of DF-enriched instant noodles

SBH was used as the DF source in DF-enriched formula because it contained high TDF especially IDF. The starting level of SBH substitution was determined by reviewing the previous research (60) which could substitute wheat flour for noodles with 30% (w/w) SBH. Thus, substituted level close to 30% of SBH should be investigated. For this study, the mixed flour was replaced with SBH varying at 15, 20, 25, 30, 35 and 40%. These substitutions of flour with SBH in the noodles caused some detrimental effects on their appearance, texture of the noodle strands. This necessitated formula adjustment in the amount of water and gluten.
5.3 Formula adjustment

Replacement with SBH caused weak and fragile noodle strands. They resulted from the decrease of wheat gluten in mixed flour that affected the amount of disulfide bond available in dough forming. Loahavaleesant (60) studied effect of gluten on noodle texture and reported that the addition of gluten could improve the noodle texture. Thus, gluten was added in order to obtain dough which was similar to the control. Then, DF-enriched formula would be further tested for noodle quality, sensory and physical quality.

The sensory results showed that as the amount of SBH in the DF-enriched instant noodles increased, the sensory scores of all characteristics decreased. This result agreed very well with earlier studies (60, 98). The reason is an increase in DF level directly affected the appearance and texture of the product and therefore, causing a decrease in overall acceptability.

In case of color measurement, as the rate of discoloration is most rapid during the first 3 hours after noodle production, it is preferable to carry out the evaluation at a fixed time (67). Therefore, all noodle dough sheets were stored for 15 min before measuring the color. According to the results of color, as percentage of SBH substitution increased, L*value or lightness decreased whereas a*value or redness and b*value or yellowness increased. It could be indicated that incorporation of SBH made the noodle dough darken and showed the reddish yellow color. Generally, consumers prefer the brightness in noodle (99). Therefore, the color suitability score in sensory evaluation was lowered. The reasons for darkening in noodle dough may be due to the remaining activity of polyphenol oxidase in both SBH and wheat flour which led to enzymatic browning. Moreover, the brown color of SBH particles could
also result in the darker dough color. These results were similar to the earlier researches. Lee et al. (80) reported that the L* value of cantonese noodle dough slightly decreased with garbanzo bean substitution and a* and b* value increased significantly. Similarly, Chompreda et al. (100) stated that the color of cooked noodles became darker with increased level of peanut flour. In addition, Knuckle (41) found that color measurement indicated the barley pastas to be darker and less yellow than the wheat pasta.

For TPA measurement, texture profile analysis presented texture properties. Hardness is a measure of the firmness of the noodles and probably the most important texture parameters (86). This parameter is related to sensory bite (87). Gumminess is the energy required to disintegrate a semisolid food to a state ready for swallowing. Chewiness is measured by “tooth packing” where the evaluator uses molar compression on the noodles and then assesses how much the noodle’s structure springs back (86). The results showed the decreased hardness, gumminess and chewiness with increasing SBH substitution. The reason for these results may be because of the interference of SBH particles in gluten and gel network. According to Ross’s study (97), the swollen starch granules released some amylose from inside during cooking. Then, the amylose released in between starch granules would gel when the noodles were cooled and formed strong bonds between the gluten strands that form the dough network. Thereby, addition of SBH in noodle dough may interfere the formation of dough network which led to lower firmness. Therefore, the softness suitability score was far from 3 when the addition level of SBH increased.

Adhesiveness is a measure of how sticky or tacky the noodles are (86). It is related to noodle stickiness to teeth at biting (87). From the results, the control instant
noodles presented the highest adhesiveness score or stickiness than other formulas. It may be caused by effect of addition of gluten in SBH-enriched formulas, but not in the control.

Cohesiveness is associated to the extent to which noodle structure is disrupted during the two compressions by the testing probe, whereas, springiness is a measure of the ability of the noodles to bounce back after pressure is applied (86). Springiness correlates with how rubbery noodles are perceived (87). The similar springiness and cohesiveness scores among all samples showed the similar noodle bite and elasticity.

Tensile strength gives an indication of how the sample holds together during cooking (86). High values of tensile strength and breaking distance in noodles are associated with noodle-eating texture (101). The higher tensile strength of DF-enriched instant noodles than the control resulted in the noodles with more strengthened network. It could be explained as the effect of added gluten. Similarly, Seib (101) stated that protein in cooked noodles would be expected to increase tensile strength, depending mostly, however, on the level present. On the other hand, the decreases in tensile strength with increasing SBH content could be explained by the weaker gel strength of starch since the fiber particles may interfere the starch gel network.

5.4 Adjustment of ratio of IDF and SDF in DF-enriched instant noodles

From the noodle quality and sensory results, the added SDF sources, which were CG, CMC and KJ, in SBH-enriched instant noodles showed no significant differences among all samples. Furthermore, it seemed to mask the gritty texture of
SBH particles. It was described that these SDF could form gel in the presence of water. Thus, the formation of SDF gel could help to disguise the rough texture.

According to color score, SDF-SBH-enriched instant noodles presented the higher L* value or brighter than the SBH-enriched formulas. Moreover, the lower a* value and b* value of SDF-SBH-enriched instant noodle formulas correlated with the lighter reddish yellow color than SBH-enriched instant noodles. The lighter color of SDF-SBH-enriched instant noodles may be caused by many factors. SDF can bind water, thus there was less free water available for browning reaction. Moreover, SDF particles provided creamy-white color. Hence, it may dilute the dark color that occurred in SBH noodles.

In term of TPA parameter, SDF-SBH-enriched instant noodles presented the higher hardness, gumminess and chewiness scores that were related to firmer texture than SBH-enriched instant noodles. These may be indicated by development of a network structure. The effect of increased firmness upon addition of SDF or gums may be attributable to formation of physically cross-linked network around the starch granules trapping them during cooking (102). Moreover, it seemed to disguise the gritty texture. There were similar cohesiveness and springiness scores among all samples that were related to similar noodle bite and elasticity. The formation of gel network by SDF increased firmness, at the same time, it presented sticky texture. These led to the higher adhesiveness score and the lower tensile strength in SDF-SBH-enriched instant noodles.
5.5 Chemical analysis of DF-enriched instant noodles and control formula

Control, SBH-enriched instant noodles and CG-SBH-enriched instant noodles were chemically analyzed using the AOAC methods. The results confirmed that TDF content in DF-enriched instant noodle product was higher than that of control formula. Furthermore, IDF and SDF content in CG-SBH-enriched instant noodles were 2 to 1 as expected. Assuming the same trend, CMC-SBH and KJ-SBH noodles would probably present a similar IDF and SDF ratio as estimated. The TDF content of DF-enriched products were increased about 4 times when compared with control formula. On a per serving basis, the product (50 g) provided about 5 g DF which equals to about 20% Thai RDI. In addition, when considering the nutrition labeling option, current regulation states that nutrition-related terms or nutrient content claims can be used on labels as specified in the Ministry of Public Health Notification No. 182/2541 (103). For term such as “high fiber” a product must have not less than 5 g DF per reference amount (serving). Thus, the term “high fiber” could be used for the DF-enriched instant noodles.

The protein content of DF-enriched instant noodles was higher than that of the control which could be explained by addition of gluten in those formulas. The ash content of CG-SBH-enriched instant noodles was slightly higher than the control and SBH-enriched instant noodles. It may be due to the ash content of CG added. Amount of carbohydrate in DF-enriched products were lower than control because of the partial substitution of DF for in the mixed flour. This also led to a slight in reduction of energy content in DF-enriched instant noodles. Consequently, the major nutritional advantage of supplementing instant noodle formulation with SBH and well-balanced proportion of IDF and SDF was a marked increase in DF content (4.3 and 4.6
times, respectively), and accompanied by a slight decrease in level of energy of the product. These DF-enriched products could be presented as an alternative food source of fiber for the consumers.

5.6 Cost of the products

The results of cost estimation (raw materials only) indicated that the cost of DF-enriched instant noodles especially SDF-SBH-enriched instant noodles were higher than that of the control. The more expensive cost resulted from the cost of gluten added in DF-enriched formulas and the imported SDF cost. Nevertheless, the cost estimation of DF-enriched instant noodles were based on a pilot-scale study. Therefore, the cost of those could be lower in a large-scale production with bulk purchase of ingredients.
CHAPTER VI

CONCLUSION

The study indicated that DF-enriched instant noodles could be formulated with SBH substitution. The maximum level of addition of SBH by replacing flour in the original formula was 15%. To improve the quality of the SBH-enriched product, it was necessary to add gluten and additional amount of water.

CG-SBH, CMC-SBH and KJ-SBH-enriched instant noodles contained a well balanced ratio of IDF and SDF as recommended i.e. 2:1.

All DF-enriched instant noodles in this study contained more TDF content whereas less energy content when compared with control formula. The TDF content of DF-enriched instant noodles were about 5 g per reference amount which equal to 20% Thai RDI, therefore it can be classified as “high fiber” products. These DF-enriched instant noodles could be consumed as an alternative food choice to increase daily dietary fiber intake and maximize health benefits.

Furthermore, these results could be used as a guide for developing the well balanced ratio of IDF and SDF in other kind of DF-enriched food products.
Recommendations for future study

1. The addition of SBH in DF-enriched instant noodles directly affected the quality characteristics especially color which caused a decrease in its sensory acceptability. Although the products formulated in this study were accepted by the panelists, adjustment of some ingredients such as addition of color additives or bleaching of SBH should be investigated to obtain desirable color and better quality characteristics of DF-enriched instant noodles.

2. Possibility of using other IDF and SDF sources for adjusting the well balanced ratio of IDF and SDF.

3. Application of a well-balanced ratio of IDF and SDF in other foods such as bakery products, Thai traditional snacks etc.
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APPENDIX A

แบบสอบถามการประมูลผลิตภัณฑ์ที่สำเร็จรูป

ตัวอย่างแบบข้อ

ผู้ประเมิน อาชีพ (......) ช่วย (......) หน่วย

วันที่ ................................. เวลา .................................

กรุณาเขียนตัวอย่างการที่เสนอและจัดเตรียมหมายเหตุ ✓ หน้าต่างรายละเอียดความชอบที่มีต่อผลิตภัณฑ์

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<th>กรุณาดูรายละเอียดของสั่นมากที่สุด</th>
<th>กรุณาดูรายละเอียดของสั่นน้อยที่สุด</th>
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หลักการจัดเรียง:

ความชอบโดยรวม (พิจารณาจากตัวแปรที่มี) ความหนักบางของสั่น ความหนักของสั่น

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หมายเหตุ: ความถี่ของการคว้าของข้อและไม่ชอบ

หมายเหตุ: ความถี่ของการคว้าของข้อและไม่ชอบ

หมายเหตุ: ความถี่ของการคว้าของข้อและไม่ชอบ

หมายเหตุ: ความถี่ของการคว้าของข้อและไม่ชอบ
## APPENDIX B

**Instant noodle formulation with six levels of SBH incorporation**

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>% flour replacement</th>
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<tr>
<td></td>
<td>Control (0)</td>
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<tr>
<td>SBH</td>
<td>15</td>
</tr>
<tr>
<td>Gluten</td>
<td>20</td>
</tr>
<tr>
<td>Water</td>
<td>34</td>
</tr>
<tr>
<td>Wheat flour</td>
<td>85</td>
</tr>
<tr>
<td>Modified potato starch (Perfectamyl AC)</td>
<td>15</td>
</tr>
<tr>
<td>Salt</td>
<td>1.5</td>
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<tr>
<td>Sodium carbonate (Na₂CO₃)</td>
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<tr>
<td>Potassium carbonate (K₂CO₃)</td>
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</tr>
<tr>
<td>Sodium tripolyphosphate (STPP)</td>
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</tr>
<tr>
<td>Guar gum</td>
<td>0.7</td>
</tr>
</tbody>
</table>
APPENDIX C

Texture profile analysis on noodles

Peak 1 = Hardness
Springiness = Length 2 / Length 1

Adhesiveness = Area 3
Cohesiveness = Area 2 / Area 1

Time (sec)

Gumminess = Cohesiveness x Hardness

Chewiness = Gumminess x Springiness
APPENDIX D

DF analysis (89, 91)

The sample of dried foods, fat and sugar extracted if containing more than 10% fat and 10% sugar, respectively, are gelatinized with heat stable α-amylase and then enzymatically digested with protease and amyloglucosidase to remove the protein and starch present. Then 95% ethanol is added to precipitate the SDF. The total residue is filtered, washed with 78% ethanol, 95% ethanol, and acetone, respectively. After drying, the residue is weighed. One of the duplicates is analyzed for protein, and the other is incinerated at 525°C and analyzed for ash. TDF is weight of the residue less the weight of the protein and ash present. Steps in the measurement of TDF are summarized in the following flow chart.

SDF and IDF fractions were determined by enzymatic gravimetric method. The method was done by filtering the enzyme digest directly (which collects IDF) and then adding ethanol to the filtrate and filtering again (which measures SDF). Steps in the measurement of SDF and IDF are summarized in the following flow chart.

Calculations

\[ \text{TDF, \%} = \left[ \frac{(\text{wt residue sample} - \text{P} - \text{A} - \text{B})}{\text{wt sample }} \right] \times 100 \]

B = average of residue weight (mg) for duplicate blank

P = weight (mg) of protein

A = weight (mg) of ash
2 x Dry sample 0.5 g + 25 ml phosphate buffer, pH 6.0 ± 0.2

Add 50 μl Termamyl solution, 15 min at 100°C

Termamyl incubation

Cool solution to room temperature

Adjust to pH 7.5 ± 0.2 by 0.275 N of NaOH solution

Add 50 μl Protease enzyme, 30 min at 60°C

Protease incubation

Cool to room temperature

Adjust to pH 4.0 – 4.6 by 0.325 N of HCl solution

Add 150 μl Amyloglucosidase enzyme, 30 min at 60°C

Amyloglucosidase incubation

Wash with 4 x 35 ml 95% EtOH, let precipitate at room temp., overnight

Filter through preweight crucible, wash with 3 x 20 ml 78% EtOH, 2 x 10 ml 95% EtOH and 2 x 10 ml acetone

Dry at 105°C, overnight

Record residue weight

Kjeldahl protein determination

Ash determination, 525°C, 5 h

Calculation of TDF

Method for TDF determination
2 x Dry sample 0.5 g + 25 ml phosphate buffer, pH 6.0 ± 0.2

Add 50 µl Termamyl solution, 15 min at 100°C

Termamyl incubation

Cool solution to room temperature

Adjust to pH 7.5 ± 0.2 by 0.275 N of NaOH solution

Add 50 µl Protease enzyme, 30 min at 60°C

Protease incubation

Cool to room temperature

Adjust to pH 4.0 – 4.6 by 0.325 N of HCl solution

Add 150 µl Amyloglucosidase enzyme, 30 min at 60°C

Amyloglucosidase incubation

Filter

Precipitate, corrected for ash, protein

4 vol EtOH

Filter

Precipitate, corrected for ash, protein

SDF

IDF

Method for IDF & SDF determination
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