PUFFING OF OKARA RICE BLENDS USING A RICE CAKE MACHINE

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The undersigned, appointed by the Dean of the Graduate School, have examined the thesis entitled

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A candidate for the degree of Master of Science and hereby certify that in their opinion it is worthy of acceptance.

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ABSTRACT

Okara is the by-product of soymilk and tofu manufactures. It is cheap and nutritious, thus has great potential to be applied in healthy snack foods. In this study, a puffed soy/rice cake product was developed and consumer preference and acceptance tests were conducted.

Okara pellets were prepared by extruding a mixture of dried okara and rice flour (3:2) (w/w) with a twin-screw extruder. Later, soy/rice cakes were puffed from the mixture of okara pellets and parboiled rice using a rice cake machine. The experiment factorial design was 4 x 2 x 3 x 3 with two replications. This was a Split Plot Design. Main plot was okara pellets and parboiled rice: 90/10, 70/30, 40/60, and 0/100 (w/w). Subplots were moisture contents: 14 and 17%, heating temperatures (221, 232, 243^{o}C) and heating time (4, 5, 6s). The cakes were evaluated for specific volume (SPV), texture, color, and integrity. All the processing factors and most interactions had significant effects. The respective decrease of okara content and increase of moisture, heating temperature and time led to greater SPV, higher hardness, darker color, and higher integrity. The consumer tests indicated that the soy/rice cake containing 70%

okara pellets was preferred to the other samples and the 90% one was liked least. The possible drivers of liking were okara pellets content, hardness, specific volume, bright color and integrity.

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CHAPTER 1

INTRODUCTION

Because of their versatile applications, soybeans have played important roles in the industries of food, medicine, and manufacturing for thousands of years in Asian countries. Soybeans mainly impressed people all over the world as a rich and cheap source of high quality protein and oil. In the early part of the last century, the healthy image of soybeans began to attract the western world and in the last 25 years, soy foods have had a significant impact on the health food market of European countries and the United States. Currently, the United States has become the largest soybean producing country in the world and owns billions of dollars of the soy foods market since the beginning of the 20th century.

Okara is soy pulp, the residue of tofu or soymilk manufacturing. It is rich in moisture, fiber and carbohydrates. Huge amounts of okara are generated every year globally due to the high production of soymilk and tofu. However, okara is hardly utilized, with most of it being discarded as waste material. This can cause serious environmental problems because of its bulkiness and susceptibility to microbial growth. However, okara has a great potential to be applied in human foods thanks to its high levels of dietary fiber and good quality protein.

The snack food market is one of the most important area of the food industry in the United States. It reached $67 billion in 1997 and is continuously expanding (Anon., 1998). The snack food market is a well-developed market with countless varieties of products, and has been an essential part in people's daily life in this country. In recent years, however, consumers have started to pay more attention to a healthy life style and a healthy diet. As a result, developing natural, low-fat, low-carbohydrate snack products has been an inevitable trend.

The puffed rice cakes industry, which is only about 20 years old, is relatively new in the snack food market. However, it is growing at an amazing speed, recently jumping from 1992's $157 million to $248.9 million in 1995 (Anon, 1996). Rice cakes are appealing to customers because of their healthy image as a low fat, low calorie, high fiber and whole grain product, and because of its savory flavors and variety of tastes. Previous studies with puffed cereal cakes include corn cakes (Hsieh et al., 1990), wheat cakes (Fan et al., 1999), sorghum cakes (Chen, 1998), barley cakes (Lee, 1999), and potato cakes (Zhuang, 2003). However, no report on puffed soy/cakes has been reported so far.

Previous studies on puffed cereal cakes indicated that the production parameters that might affect the cake quality included tempering moisture, heating temperature and heating time. The cake quality could be described in the terms of specific volume, hardness, lightness, redness, yellowness and integrity or weight loss after tumbling.

The objective of this study, therefore were:

1. To puff soy/rice cakes from okara, rice flour and parboiled rice using a rice cake machine.
2. To determine the quality of puffed soy/ rice cakes in terms of specific volume, hardness, lightness, redness, yellowness and integrity.
3. To study the effects of okara content, moisture content, heating temperature and heating time on the quality of puffed soy/rice cakes.
4. To study consumer preference and consumer acceptance of the soy/rice cakes.

CHAPTER 2

LITERATURE REVIEW

2.1 Soy Foods

In China, where soybean is valued as “vegetable meat”, people call it “da dou”, which means “great bean”. In the United States, the soybean has also been dubbed “the miracle bean”. Worthwhile for this honor, the little round legume is useful and versatile all over the world for its limitless applications. Currently, people are familiar with soy because it is an efficient and cheap source of high quality protein and seed oil. Soy is utilized industrially for everything from soap to animal feed to environmentally friendly ink. Even Henry Ford once wore suites made of soybeans (Myers, 1993). In 2002, a $3.5 billion market for soy foods in the United States indicates that it is no longer a niche market any more (SPINS & Soyatech, Inc., 2002).

2.11 History and Consumption of Soy Foods

Soybean has a rich and mysterious history, which began over five thousand years ago. On the windy plains of eastern Asia, the ancient strips of the legume grew wild on vines and later were discovered and tamed by early Chinese farmers (Messina et al., 1994).

The importance of the soybean as a food can be seen in historical records. The Chinese emperor, Sheng Nung, who lived five thousand years ago, named soybeans one of the five sacred crops in his masterwork, “Sheng Nung Ben Cao”, written in the year 2838 B.C. (Adolph et al., 1920). In addition to being an important food, soy has also played a role in medicine. Li Shi-Chen, the greatest herbalist in Chinese history, said in

“An Outline of Materia Medica”, A.D.1578 that soybeans are an effective remedy for kidney disease, water retention, and poisoning. Soybeans are also believed by the Chinese to cure the common cold, skin disease, beriberi, diarrhea, toxemia of pregnancy, constipation, anemia, and leg ulcers (Lu, 1990).

Once cultivated by Chinese farmers, soybeans spread slowly across northern and southern China, into Korea, Japan, and Southeast Asia (Simoons, 1991). It appeared in Japan during 800 A.D. and entered Europe one thousand yeas later (Messina et al., 1994). European traders and missionaries may have brought tofu back with them from Asia in as early as the sixteenth century.

In the nineteenth century, Chinese immigrants brought traditional Chinese fare, including soybean products, to the American cities where they settled. However, outside of those communities, soybeans were virtually unknown to Americans. By the early part of the century, scientists were already interested in soy for the treatment of diabetes and anemia, as infant food and as car materials (Shurtleff et al., 2004; Friedenwald et al., 1910; Adolph et al., 1932; Tso, 1929 & 1931). By the 1920s, Dr. John Harvey Kellogg, “the Father of Soybean”, gave Americans the first impression of soy by developing and championing the first Western soymilk and meat substitutes (Shurtleff et al., 2004). Only for the last 25 years have soyfoods began to make a significant impact on Western cultures and diets (Peter Golbitz, 1995).

Currently, about one-half of all the soybeans grown in the world are produced in the United States. Soybeans are the all-American crop, ranking right behind corn in importance. But one third of them are exported to other countries and about 90 to 95 percent of the soybeans that stay in the United States are fed to agricultural animals.

Isolated from the protein and starch portions of the beans, soy oil plays an important role in the American diet. In the United States, soybean oil is made into about 80% of all the cooking oils on the market (Synder et al., 1987). Most solid shortening and margarines contain soy oil, as do most commercial baked goods, fried snack foods, frozen fried foods, canned or dehydrated foods, imitation dairy products, and processed meat products (Messina et al., 1994).

Americans also eat a small amount of soy protein. Soy isolates and soy concentrates are added to hundreds of foods in small quantities, such as baked foods, whipped toppings, soups, gravies and processed meats, mainly for their chemical properties, like for thickening or emulsification (Synder et al., 1987). Soy protein has been used as a meat extender, which has been used in school lunch programs since the early 1970s (Synder et al., 1987). Tofu, one of the few soyfoods familiar to most Americans, was recommended to be used as a meat alternative in school lunches by the American Dietetic Association in 1986 (ADA, 1986).

Soyfoods are becoming the mainstream with a growing number of health-conscious consumers. During the past decade, interest in traditional Asian soyfoods has soared in the U.S. as reported in the September, 2002 issue of Food Product Design, and soyfood market growth is “expected to hit $6 billion in sales by 2005” according to a report on MarketResearch.com.

2.12 Nutritional Benefits of Soy Foods

Soy products have been shown to play an important role in health. Soybeans have been prized for their remarkable ability to produce over 35% protein by weight, more than any other unprocessed plant or animal food (Shurtleff et al., 1975). Two factors determine soy protein quality - digestibility and the pattern of essential amino acids (Messina et al., 1994). Most commercial soyfoods are easy to digest. Tofu, for example, is more than 92% digestible; soy flour, about 85-90%; and soy protein isolates, about 95% (FAO, WHO and UNU, 1985; Synder, 1987; Bressani, 1981). Only toasted or steamed whole soybeans are poorly digested. Soybeans contain all of the eight essential amino acids in a configuration readily usable by the human body (Shurtleff et al., 1975). Despite its limiting amino acid, methionine, the amino acid pattern of soy protein matches well with those of human requirements. Therefore, there is actually no essential difference between soy protein and animal protein in eggs, milk and meat.

Soybeans are also rich in other nutrients, such as calcium, iron, zinc, and many of the B vitamins and vitamin E (Messina et al., 1994). As an excellent source of fiber (15% by weight), soybeans carry an extremely low ratio of calories to protein (Shurtleff and Akiko, 1983). Containing no lactose, soyfoods provide a nutritious and wonderful selection of alternatives to dairy foods for people who are lactose intolerant. Inexpensive soyfoods have no cholesterol and almost none of the relatively indigestible saturated fats found in most animal foods. Soy oil only contains monounsaturated fats and polyunsaturated fats that do not increase cholesterol. But the most interesting thing about soy oil is that it contains as much as 8% linolenic acid, which is an *omega-3* fatty acid that may help reduce the risk of heart disease and may even help to prevent cancer

(Dolecek, 1992; Wallingford et al., 1991; Israel et al., 1992). In 1999, the U.S. Food and Drug Administration authorized a health claim acknowledging that “Diets low in saturated fat and cholesterol that include 25 grams of soy protein a day may reduce the risk of coronary heart disease (CHD) by lowering blood cholesterol levels.” In addition, soy also naturally contains isoflavones, compounds that have been shown to reduce the risk of certain cancers (USB, 2001).

2.13 Traditional Soy Products

Traditional Asian soy foods are divided into two categories, non-fermented and fermented. Non-fermented soyfoods include fresh green soybeans, whole dry soybeans, soy nuts, soy sprouts, whole-fat soy flour, soymilk and soymilk products, tofu, okara and yuba. Fermented soyfoods include tempeh, miso, soy sauce, natto and fermented tofu and soymilk products. Westerners have adopted some of these foods wholeheartedly. The most popular soyfood in the United States currently are tofu, soymilk, soy sauce, miso and tempeh. A new class of “second generation” soyfoods includes such products as tofu hot dogs, tofu ice cream, veggie burgers, tempeh burgers, soymilk yogurt, soymilk cheese, soy flour pancake mix and a myriad of other Americanized soyfoods (Golbitz, 1995).

In many less developed countries, commercial soy-based foods were imported from the West. Centrally processed nutritious blends of cereals and soy, through the well-known principle of protein complementation, as reported by Bresani (1977), offer the most effective weaning food and have made major contribution to reducing malnutrition. With the development of technology in food processing, extrusion became a versatile, cost effective and energy efficient alternative for central processing of soy-based foods, which makes it possible to supply weaning foods through local manufacturers within less developed countries (Harper, 1984).

2.2 Okara

The insoluble carbohydrate residue left from ground soybeans after extraction of the water extractable fraction used to produce soymilk and tofu, is called okara (pronounced oh-KAR-uh). Okara is beige in color and has a light, crumbly, fine-grained texture, which makes it look like moist sawdust or grated coconut (Shurtleff et al., 2004).

About 1.1 kg of okara is produced from every kg of soybeans processed for soymilk (Khare et al., 1995a). In Japan, about 700,000 tons of okara were produced from tofu production in 1986 (Ohno et al., 1993). Today, around 150 million metric tons of soybeans are produced globally with 50% grown in the U.S. In the U.S., only 1% of the soybean is used as human food and soymilk and tofu occupied the top line of soy products (Liu, 2000).

Okara used to be considered as having little market value. Most of the okara from Japanese and American tofu shops and “soy dairies”, that produce soy-fortified dairy products, such as soy yogurt, soy ice cream, soy cream cheese, were fed to dairy cattle. Its disposal has so far been viewed as a bottleneck for food industries because this causes severe environmental problems due to its susceptibility to yeast spoilage and its bulkiness. The use of okara as human food is constrained by its high level of moisture and dietary fiber. Though underutilized, okara is a rich source of good quality protein and dietary fiber (Vander Reit et al., 1989 and Matsuo, 1990). With the growing concern of health issues by consumers and the awareness of the importance of dietary fiber in human diets, okara may have potential to be applied in human foods.

2.21 History of Okara

2.211 Etymology

The word “okara” comes from Japan. The character “o” before the word “kara” is an honorific prefix for the simplest and most humble of foods in Japan, while “kara” means “shell, hull or husk”. Thus, translated literally, “okara” means “honorable shell.” Okara also has different names in other Asian countries, such as “dou cha” (Chinese), “bejee” (Korean), and “tempe gembus” (Indonesian) (Liu, 1997).

Okara used to own a remarkably large numbers of names in English until the 1970s. “The Farm”, an international, spiritual community founded in 1971 in Tennessee, introduced the term ”soy pulp” in 1974, and Shurtleff and Aoyagi (1975) introduced the Japanese term “okara” in their “Book of Tofu”. Discussions on the merits of each term, resulted in the use of both interchangeably, but "okara" was preferred because it was shorter, neutral and inviting when used to describe foods.

2.212 History of Okara in East Asia

Tofu and soymilk have been very popular in East Asia since early times. Before World War II, okara was sold in most tofu shops for use in cooking. Therefore, a great amount of okara was produced and the majority of it has always been used as livestock fodder, with a portion being used as organic fertilizer. Sometimes, however, it is also utilized as human food, especially in poorer countries.

Since early times, okara has been very popular in Japan as an important basis for making dishes at home, in fine restaurants and delicatessens. The most popular dish is called “Unohana-iri”, made by stir-frying okara with minced vegetables and simmering the mixture in a sweetened soy sauce. The earliest scientific investigation on okara and its nutritional impact was also done by the Japanese researchers Kano and Iishima of the Tokyo Army Medical College in 1989. They found that 79% of the protein was digestible and Oshima published the result in English in 1905.

In China, many tofu makers also run small hog farms and use okara as their main sources of fodder. In some areas, okara is pressed, inoculated with *Actinomucor elegans* spores and incubated for 10-15 days to make the fermented nutritious flavoring cake food called "meitauza" (Shurtleff et al., 2004).

In Indonesia, a large proportion of okara is used as human food. The most popular products are okara tempeh (cakes of okara fermented with *Rhizopus* mold spores) and okara onchom (similar but orange-colored cakes fermented with *Neurospora intermedia* spores), which is well liked for its tasty almond-like flavor (Shurtleff et al., 2004).

2.213 History of Okara in Europe

The earliest reference known in the west is by German Kellner in 1989. The report, named "Tofu Cakes", gave okara compositions on both wet and dry basis and its utilization as animal fodder and fertilizer. Li Yu-Ying (1912) was the first to discuss the use of okara as food and he also made tofu and soymilk in Paris. "The Lancet" in England (1915) noted in an article on soymilk that okara has been used in bread making. With the spread of tofu shops throughout Europe in the late 1970s, okara has been applied in a variety of ways similar to those in the United States (Shurtleff et al., 2004).

2.213 History of Okara in the United States

The earliest known reference to okara in the United States was by a Japanese researcher named Oshima in 1905, which cited the general composition and the utilization of okara in Japan. In 1929, T.A. Van Gundy commercialized “Soy Spread”, an okara-based product. In 1931, Morse, of the USDA, mentioned that okara could be used in various Western-style recipes including stuffed green peppers, gingerbread, macaroons, and chocolate fudge. In 1932, Madison Foods began making and marketing a “steak like meat analog” made from wheat gluten and okara. In 1938, Whiteman and Keyt of the USDA published a recipe for Okara Macaroons (Shurtleff and Aoyagi, 2004).

In 1960, the first study of okara in its relationship to tofu making were published by Smith, Watanabe and Nash, who did extensive okara recovery studies on many varieties of US soybeans. Later, Hackler and co-worker (1963, 1967) did the first modern nutritin study on okara.

“The Farm”, in Tennessee, played an essential role in popularizing okara in the U.S. They began to make soymilk in early 1972 and experimented with using okara to make tempeh shortly afterwards. In 1974, they published a 14-page booklet containing a description of okara and six American-style recipes, including Soy Pulp Burgers, Scalloped Potatoes and Pulp, Soysage, Protein Spice Cake, Soy Pulp Cookies, and Soyola (Soy Pulp Granola). The Book of Tofu (Shurtleff and Aoyagi, 1975) first introduced the name of “okara” in an entire chapter.

In the late 1970s, three new concepts generated new interest in okara: the importance of fiber in a healthful and balanced diet, the value of not wasting and recycling and the interest in vegetarian diets and meat substitutes (Shurtleff and Aoyagi, 1975). Martha Wagner helped popularize the use of okara by writing "Okara: The Little-Known Superfood" (New Age magazine, 1980) and "Cooking with Okara" (Vegetarian Times, April 1982); each gave recipes. Okara began to be used like the newly popular wheat bran.

Currently in the United States, a great amount of okara is produced everyday in tofu shops and tofu dairies. Therefore, these okara producers have to find creative ways to use it efficiently. Commercial okara products are available at some Japanese and Chinese groceries and fresh okara can be found at all tofu shops easily. So far, the most popular commercial okara-based product was “Soysage”, developed by “The Farm”. Loma Linda Foods, one of the large soymilk producers in 1970s, tried to sell drum-dried okara to the baking industry as a protein supplement. Other new trends for utilizing okara is to use it as a fermentation substrate for ethanol or methane production or an organic fertilizer.

2.22 Composition of Okara

The proximate composition of okara will depend on the amount of water phase extracted from round soybeans, and whether further water is added to extract residual extractable components. With a moisture content of 84.50%, the proximate composition of wet okara is 4.73% protein, 1.5% lipid, 7.0% sugars, 1.5% fiber and 0.4% ash at pH 6.7. A summary of the proximate compositions found on a dry matter basis in five studies is shown in Table 2.1.

Table 2.1. Percentage protein, fat/oil, crude fiber, and carbohydrates, on a dry matter basis, in okara.

Protein (%)	Crude fat/oil (%)	Crude fiber (%)	Carbohydrate (%)	Reference
24.0 (18.2-32.2)	15.2 (6.9-22.2)	14.5 (9.1-18.6)	-	Bourne et al. (1976)
25.4 - 28.4	9.3-10.9	52.8-58.1	3.8-5.3	Van der Riet et al. (1989)
27.1	7.6	-	-	Wang et al. (1989)
26.8 ± 1.0	22.3 ± 1.5	-	-	Guermani et al. (1992)
26.8	12.3	-	5.29	Ma et al. (1996)

2.221 Dietary Fiber in Okara

Okara, soy bran and soy isolate are the three basic types of soy fibers. “Dietary plant fiber” is now considered an essential part of a well-balanced daily diet. It is composed of carbohydrates found in other bran layers of whole grains and the cell walls of natural vegetables and pulses. Generally, dietary fiber in foods has been established to improve gastrointestinal functions (Anderson et al., 1990; Kay, 1987). Fiber is classified as either soluble or insoluble. Water soluble fibers have shown competency in lowering elevated blood cholesterol and balancing sugar levels, whereas the water insoluble part has been shown to increase fecal bulk, reduce transit time and improve bowel functions (Khare et al., 1995).

The crude fiber reported by Van der Riet et al. (1989) is significantly higher than that reported by Bourne et al. (1976), but the soluble fiber levels reported by both are quite similar. Okara is mainly composed of insoluble fiber, ranging from 40.2 to 43.6% on a dry basis (Table 2.2).

The fiber components were reported by Guermani et al. (1992) to be 12.1 ± 0.2% hemicellulose, 5.6 ± 0.9% cellulose, 11.7 ± 1.4% lignin and 0.16 ± 0.07% phytic acid. Although the phytic acid composition is different from that reported by Van der et al. (1989) (Table 2.2), it is found mainly concentrated in tofu (Saio, 1979).

2.222 Protein, Fat and Carbohydrates in Okara

Okara accounts for 29.6% (27.6 - 30.6), 20.2% (17.8 - 22.3), and 11.4% (11.1 - 12.0) of original soybean solids, protein, and oil, respectively (Wang, 1989). Containing about 17% of the protein in the original soybeans, okara itself consists of 3.5% protein by weight, or about the same proportion found in whole milk or cooked brown rice (Shurtleff et al., 1975). Soybean fractions include okara, soymilk, and tofu, all of which have a similar ratio of essential amino acids to total amino acids (E/T). But the threonine and valine contents of okara are higher than those found in soymilk and tofu (Wang, 1989). Okara has a higher quality protein as calculated by the Protein Efficiency Ratio (PER) (okara = 2.71, milk = 2.86) than any other soybean fraction in the tofu making process (Hackler et al., 1963, 1967; Shurtleff et al., 1975), largely due to its high content of limiting essential amino acids, cysteine and methionine, which have been proven to be similar to the FAO scoring pattern, and high (80%) *in vitro* protein digestibility (Ma et al., 1997; Khare et al., 1993). In Waliszewski's research (2002), okara was found to be an excellent supplier of lysine (80.9g/Kg of protein) and tryptophan (118% of FAO/WHO requirement) to enrich tortilla.

Table 2.2. **Proximate composition, mineral analysis and vitamin analysis on a dry matter basis of okara prepared from three cultivars of soybeans (Van der Reit et al., 1989).**

Proximate Composition, (g/100g)							
Total fiber	Soluble fiber	Insoluble fiber	Phytic acid	Carbo-hydrates	Oil	Protein	Cultivar
56.6	14.6	42	0.5	5.3	9.6	28.4	Edger
58.1	14.5	43.6	1.2	3.8	10.9	25.4	Hutton
52.8	12.6	40.2	0.9	4.6	9.3	26.2	Prima

Minerals and Vitamins, (mg/100g)													
Nicotinic acid	Riboflavin	Thiamin	P	Mn	Zn	Cu	K	Na	Fe	Mg	Ca	Ash	Cultivar
1.01	0.04	0.59	396	2.5	3.8	1.1	1046	16.2	6.2	163	260	3200	Edger
0.82	0.03	0.49	444	3.1	3.5	1.1	1094	19.1	7.2	158	428	3700	Hutton
1.04	0.03	0.48	407	2.3	6.4	1.2	1233	18.4	8.2	165	286	3000	Prima

[a] Kjeldahl nitrogen x 5.71.

Okara is also rich in oil, ranging from 7.6 - 22.3%. (Table 2.1). The appreciable amount of protein and oil of okara emphasizes the fact that it is not a waste product.

Compared with the prior two components, the total carbohydrate level (not including fiber) is relatively lower, at about 3.8 - 5.3% (Table 2.1). Nevertheless, it is slightly higher in okara than in tofu and the concentrations would be sufficient to encourage the growth of carbohydrate utilizing microorganism (Van der Reit et al., 1989). The value of simple carbohydrate fractions in Table 2.3 indicates a low amount of soluble carbohydrate materials, including monosaccharides and oligosaccharides, which are mainly lost in the whey during tofu-making. Monosaccharides present in okara include fructose, rhamnose and arabinose (Smith et al., 1972). The major sugars identified in soybeans are sucrose, raffinose and stachyose, which are much lower in okara. Starch is a minor constituent of soybeans (Bils and Howell, 1963; Wilson et al., 1978) but relatively high levels were nonetheless recovered in tofu and okara. The water-soluble polysaccharides hydrolyzed from okara could have potential as food emulsifiers (O'Toole, 1999).

Table 2.3. Carbohydrate contents (g/100)), on a dry matter basis, of okara from three cultivars of soybeans (Van der Riet et al., 1989).

Cultivar	Monosaccharides (Unspecified)	Oligosaccharides			
		Stachyose	Raffinose	Sucrose	Starch
Edger	0.7	1.4	0.3	2.3	0.59
Hutton	0.6	0.9	0.3	1.3	0.68
Prima	0.7	0.9	0.4	1.8	0.79

2.223 Vitamins and Minerals in Okra

According to the element analysis by Nakayama et al. (1997), okara, on a dry matter basis, contains 46.3% C, 6.99% H, 3.99% N, 0.25% S, and 3.59% ash. The mineral values in commercial okara from the Indian tofu industry as reported by Khare et al. (1995a) and the report on Ca, Mg, P and Zn by Ikeda and Murakami (1995) are similar to but on the lower side of the mineral report for the Edgar cultivar (Table 2.2) by Van der et al. (1989). Soybeans are rich in potassium and phosphorus, with the former, together with sodium, being significantly concentrated in okara (Saio et al., 1969a, b; Saio, 1979). The ash values reported by Van der et al. (1989) are close to those by Nakayama et al. (1997), but lower than the value reported by Ma et al. (1996) of 4.54%. Significant levels of vitamin B, especially thiamin and nicotinic acid, are recovered in okara. Khare et al. (1995a) reported similar levels of vitamin B groups (riboflavin, thiamin and niacin) compared with Van der et al. (1989) (Table 2.2).

2.23 Manufacture and Preservation of Okara

In tofu shops, okara is traditionally made during tofu manufacture. The soybean is soaked and cooked, and the slurry transferred to a heavy cloth sack set on a rack on a wooden curding barrel. The sack is pressed either with a traditional lever or with modern equipment. Liquid soymilk filters through the sack into the curding barrel while okara remains in the sack (Shurtleff et al., 1975).

Similar production of okara as a byproduct of soymilk making was also described in Liu (1997). Basically, soaked or unsoaked soybeans (or dehulled ones) are ground with water. The fibrous fraction (okara) is then separated from soymilk, either before or after the slurry is heated.

After the extraction of soymilk from cooked soybeans, the remaining okara is wet to slightly damp depending on how efficient the water phase is removed from the draff. The high moisture content and water activity of okara bring significant problems with its utilization in handling because fresh okara can be spoiled by yeasts in hours and it is very bulky or “messy”, containing about 80% water (Noguchi, 1987). Therefore, it is important to preserve okara prior to its utilization.

There are generally two ways to preserve okara. One is to ferment it using lactic acid bacteria to preserve against microbial spoilage. Kato et al. (1986) found that spoilage was efficiently prevented by inoculating okara (1% glucose added) with 10^6 cfu of dried lactic acid bacteria (*Lactobacillus plantarum*) starter/g and incubating in semi-anaerobic conditions at 30-37°C. When lactic acid fermentation occurred, the pH value was lowered to less than 4.2, which inhibited growth of spoilage bacteria at 37°C for 4 days or longer. With yogurt and other fermented milks there are considerable opportunities for exploiting lactic acid bacteria as probiotic cultures. Therefore, probiotic-fermented okara may have potential to be added into human foods such as soymilk or soy yogurt to enhance their nutritional functions by improving gastrointestinal health of humans.

Another way to preserve okara is to dry it soon after production. Muramatsu et al. (1995a-c) studied the dehydration and cohesion properties of okara using added water absorbing synthetic polymers in various forms. Hirotsuka et al. (1987) of the Fuji Oil Co. Ltd. obtained a U.S. patent for a process of drying okara while preserving its desirable qualities of water binding capacity and whiteness. Okara can be dehydrated on a drum dryer to make a dry staple; the Johnson Boiler Co. in Japan makes drum dryers specifically designed for drying and flaking okara. Dried okara might be able to be milled to produce high-fiber soy flour, which could be used as is in breads or roasted like *kinako*.

2.24 Utilization of and Products Made from Okara

Upon good preservation, okara can be applied in many fields, either in non-food or human food industry. Okara may or may not be utilized directly as a food. With the realization of its value, food scientists are trying to extract nutrients from okara. On the other hand, okara is consumed mainly by Asians as a traditional common food or even served as a popular dish. It can be incorporated into soups or other foods, fried, or fermented to attain a special flavor. Food products made from okara are not rare. They can also be divided into two categories, fermented and non-fermented.

2.241 Non-Food Uses of Okara

Traditionally, non-food utilization includes using okara as livestock fodder, organic compost and pet food. Most of the okara from Japanese and American tofu shops and soy dairies are fed to dairy cattle or hogs at a very low price (several cents a pound). In cities, some shops give it away or even have to pay farmers to truck it away. Not limited to ruminates, who can digest crude fiber and use it as a nutrient source, okara makes a good addition to household or commercial dog or cat foods as well. In Japan, large factories sell much of their okara output to pet food manufactures. Additionally, okara has been used as a base for an artificial food for silkworms to reduce costs and to even out production throughout the year (Sumida et al., 1995).

In addition to being used as animal feed, okara is added to compost piles or turned directly into soil in order to add nitrogen and organic nutrients, while helping to aerate and lighten heavy soils. As described in a Japanese patent (Hasegawa, 1998), okara has also been used to make reinforced ceramic products using the pozzolanic reaction.

Recently, a number of studies have involved the use of okara as a base for fermentation. Ohno et al. (1996) used okara as a base for *Bacillus subtilis* NB22 to produce iturin A, an effective fungicide against serious plant pathogens. Khare et al. (1995a) applied a solid-state fermentation on okara with *Aspergillus terreus* NCIM 653 and *Aspergillus niger* NRRL 330 for the production of citric acid (a preservative added to foods and soft drinks to add a sour flavor). Kitamura et al. (1996b) produced ethanol from saccharified okara using yeasts, and Hayashi et al. (1989) also found that the mold, *Penicillium simplicissimum* AK-40, isolated from soil, produced two novel compounds with insecticidal properties when grown on okara.

2.242 Fractionation of Okara

Okara has not manufactured as human food much in the U.S. yet, due to the difficulty in its handling. With the development of more sophisticated food processing techniques and the growing awareness of the importance of crude fiber in diets, however, okara is receiving more and more attention from food scientists. Recently, research on the utilization of the fractionation of okara as nutritional supplements and textural additives in other foods is becoming popular. Since okara is a cheap and rich source of good quality protein and dietary fiber, various methods to isolate pure protein and amino acid fractions from okara for its suitability as a food protein was studied (Wang, 1989; Khare et al., 1993; Ma et al., 1997; Chan et al., 1999). Food scientists are also seeking ways to separate hemicelluloses, which can lower cholesterol levels, and other pectic polysaccharides from okara to increase tofu yields (Takahachi, 1968), or to produce a low-viscosity, water-soluble carbohydrate that can be used to stabilize soluble proteins (Maeda et al., 1998).

2.243 Fermented Okara Products

For fermented okara products, lactic acid bacteria and fungi have been mainly employed. Fermented okara was found to have a different composition from its natural counterpart, being rich in hemicellulose, significantly lower in lipid, lignin, stachyose, raffinose, and phytic acid (Guermani et al., 1992), and apparently containing an increased amount of the antioxidant, N-telopeptide (NTX) (Yokota et al., 1996a). Hemicellulose plays a role at lowering cholesterol levels in the human body. Certain amounts of stachyose and raffinose may cause meteorism and flatulence, and phytic acid in okara may reduce Ca^{++} balance and reduce the availability of some metal ions (Matsuo, 1996). Fermented okara has been shown to modify colonic conditions in a positive way (Matsuo, 1991) by lowering plasma and liver cholesterol levels and triglyceride levels in rats (Matsuo and Hitomi, 1992), and increase sterol excretion in rats' feces (Matsuo, 1996). Food scientists found that although natural okara may have some antinutritional qualities, such as raffinose and stachyose which cause meteorism (flatulence), fermented okara has definite advantages in a diet as shown below.

Okara Natto

Natto is a fermented soybean product made by using the bacteria, *Bacillus natto.* It is typically served with Japanese breakfast and is well-known for preventing heart attacks, strokes, cancer, osteoporosis, obesity and intestinal diseases caused by pathogens. Matsumoto and Take (1980) tried to make a natto-like product by replacing okara with whole soybeans, and found that one strain of *B. natto* can produce comparable biochemical and organoleptic characteristics (Liu, 1997).

Meitauza

The traditional Chinese product, named "**meitauza**" (*Mucor*-fermented okara), was first described by Y.K. Shin in 1937. It is served either fried or cooked with vegetables, and is widely considered to be a tasty and nutritious food. *Mucor* is a synonym for *Actinomucor elegans*, already noted as one of the principle fungus involved in the preparation of fermented tofu (Liu, 1997).

Okara Tempeh

Traditional tempeh originated from Indonesia, popularized Japan later and may storm the Western world in the future. It is a chunky, tender, cake-like product usually served with rice as part of a main meal or sometimes by itself as a snack (Indiana Soybean Board, 1997). Easily digestible, tempeh is nutritious, providing valuable vitamin B groups, including vitamin B12 (Shurtleff et al., 1979).

Incorporating okara into tempeh was described as one of the most creative ways to utilize large amounts of okara (Shurtleff et al., 1979). Matsuo (1989a, b) fermented okara using the tempeh fungus, *Rhizopus oligosporus*, and the koji fungus, *A. oryzae*, to improve the nutritional value of traditional tempeh as a high-fiber, low energy foodstuff. The fragrant mycelium of *Rhizopus* binds the okara together into the cakes or patties and the fermentation only takes about 22 h. In restaurants, the finished product is sliced and fried until crispy and golden. It has savory organoleptic properties, containing no beany flavors, having a very smooth mouthfeel and a texture like chicken or seafood fillets (Shurtleff et al., 1979).

Okara Onchom

Another popular Indonesian fermented product is Onchom (or spelled as Ontjom), a close relative to okara tempeh. It is made and served in the same way as tempeh but fermented using a different culture, *Neurospora* mold, which envelops the cake with its brilliant orange mycelium (Shurtleff et al., 2004). The finished product has a reminiscent flavor of walnuts or almonds (Shurtleff et al., 1979).

2.244 Non-Fermented Okara Products

Non-fermented okara products appeared earlier than did the fermented products. In 1983, Nolan reported that the Haarman and Reimer Corp. in the U.S. developed an okara bar. Noguchi (1987), of the Japanese National Food Research Institute, Ministry of Agriculture, patented a process whereby okara is converted to a soybean product by extrusion. Also, productions of a low-calorie food based on okara are covered by at least one U.S. patent (Watanable et al., 1997) held by Ajinomoto Co., Inc.

Soysage

Soysage is a tasty sausage-like product, developed by “The Farm” in Tennessee, currently commercially available in a number of U.S. tofu shops and tofu dairies. It contains okara, whole-wheat flour, wheat germ, nutritional dry yeast food supplement, oil, soy sauce, honey, herbs, and spices (Shurtleff et al., 1975). It is nutritiously packed and can be manufactured in large quantities easily. To serve, it is sliced into small round pieces and fried to a golden brown color, and then put in sandwiches or pizza like a breakfast sausage, or mashed and used like a vegetable paté (Shurtleff et al., 1975).

Soysage paté is served in sandwiches at White Wave Foods Company. Other ingredients include soysage, tofu, soymilk mayonnaise, mustard, celery, pickles, and sunflower seeds (Shurtleff et al., 1975).

Baked Products

Okara contains about 14.6% soluble fiber on a dry weight basis, versus 4% in wheat bran. Some tofu shops are connected to bakeries because okara can be used in a variety of western-style baked products. It not only adds natural fiber and protein, but also gives a unique crumbly texture to breads, muffins, pancakes, donuts, brownies, fudge cookies, okara granola, okara and tofu gingerbread, and okara and grain burger. Recipes were offered in “The Book of Tofu” (Shurtleff et al., 1975). However, the amounts of okara added were not high (usually lower than 10% fresh okara) (Shurtleff et al., 1975). Khare (1995) fortified biscuits with okara and found a supplement of 60% (by weight) of fresh wet okara, or about 12% of okara on dry basis, was the most acceptable. Kao and Chen (1998) applied okara on cookies with the addition of up to 30% of the dried powder of okara without adverse effect on the sensory properties of the products. Food scientists are trying to increase the amount of okara added to baked foods or other snacks without having a bad impact on sensory characteristics, thereby enhancing the proportion of natural soy in traditional foods and meanwhile raising the efficiency of okara utilization.

Others

Okara and vegetable sauté is prepared using okara, and the product is available in some delicatessens or natural food stores in Hawaii and Japan. It is sold chilled and the recipe is provided in “The Book of Tofu” (Shurtleff et al., 1975).

Okara can also be used in salads (with mayonnaise, sliced vegetables and seasonings), in miso as a substitute for soybeans, in breakfast cereals, and in hamburger extender. Further, toasted okara may also be served in party mix with nuts, sunflower seed, coconut, raisins and so on.

2.3 Snack Foods

A snack food is defined as “a type of food to temporarily tide a person’s hunger and provide a brief supply of energy for the body”. Snack foods are “less perishable, more durable and more appealing than natural foods” (Wikipedia Encyclopedia, 2005). The snack food industry is an important part of the American food industry. It evolved from a $12 billion market in 1990 to $67 billion in 1997 (Anon., 1998) and is still growing.

Many in the West perceive snack foods as “junk foods” because most contain substantial amounts of carbohydrates, sweeteners, preservatives, and other savory ingredients, such as chocolate chips, peanuts and special flavors (Wikipedia Encyclopedia, 2005). Flour, chocolate, confectionary, chips and popcorns are considered as having little or no nutritional value, and are not seen as contributing to physical and mental health. Therefore, food scientists and manufacturers are striving to develop healthier snack foods.

A healthy snack is sold on the basis that it is healthier than a conventional counterpart, such as low-fat chips, or if it is usually bought by consumers who perceive it to be healthier, such as carob-based confectionary (Booth, 1990). Many new forms of ingredients and food additives contributed to the “engineering” of novel healthy snacks. These snacks were prepared by incorporating special proteins, particular fats, and certain carbohydrates, including dietary fiber, into their formulation to attain nutritionally balanced food products in accordance with the latest nutritional theories (Lachmann, 1969). A large number of them are based on soy, such as tofu and tempeh, and rice, such as precooked rice and rice ball. Recently, the terms, "low fat," "no-fat," and "light", have become the words of health-conscious individuals. The trend has seen the popularity towards puffed snacks (Booth, 1990).

2.31 Rice Cakes

Puffed snacks play an important part in the American diet. It is a newly developed branch in the food industry and is still growing fast. Currently, diversified products are available on supermarket shelves. Successful ones have been made in the form of cakes generally manufactured of puffed corn or rice. Rice cakes have a distinctive popcorn-like flavor that many enjoy. A large number of rice cake consumers love it because of the health benefits of whole grain, low calorie snacks. Rice cakes contain only 35 calories, or 10 g per cake, and have a natural food image. In addition, they are rich in bran and dietary fiber, which are known to be highly effective in reducing cholesterol levels in humans (Anon., 1989b; Kahlon et al., 1990; Saunders, 1990).

Shares of snack foods held by rice cakes have increased in recent years with the introduction of various flavored products. Supermarket sales of rice cakes jumped from 1992's $157 million to $248.9 million in 1995 (Anon, 1996). Major companies, such as Quaker Oats, Sunfresh, Lundberg, Hain Food Groups and Hunt-Wesson have successfully marketed rice cakes in the U.S.

Following the lead of puffing rice cakes using only rice, food manufacturers have made efforts to incorporate other ingredients to add nutritional value or specific flavors. Many studies have been conducted to produce more healthy puffed rice cakes, such as corn cakes (Hsieh et al., 1990), wheat cakes (Fan et al., 1999), sorghum cakes (Chen, 1998), barley cakes (Lee, 1999) and potato cakes (Zhuang, 2003). However, there has been no report on soy/rice cakes so far.

2.32 Manufacture of Puffed Soy/Rice Cakes

Puffing is a process that involves the release and expansion of a gas from the inside of a product to cause expansion or rupture of an existing structure in order to create a new internal structure (Payne et al., 1987). There are two ways to produce puffed snack foods, according to Park (1976). They are: (1) atmospheric pressure puffing, which relies on high temperature to achieve rapid vaporization of moisture, and (2) pressure drop procedure, which depends on the sudden release of pressure on superheated moist materials, causing flash vaporization of moisture, and the resulting puffed product. Puffed rice cakes are made based on the second principle. An adequate level of starch is required to provide structure when the product is puffed in hot oil or air (Frame, 1994).

Because of its fibrous property, okara cannot be puffed directly. Therefore, okara need to be mixed with rice flour and processed through extrusion to form pellets before puffing. These pellets are indirect expanded snacks, also called "third generation snacks" or "half product" (Frame, 1994). They can be made from a blend of cereal grains composing flour and other additives, such as fiber, protein and flavors. The blends are cooked in an extruder and forced through a die at relatively low temperature (below $100^{o}C$) to prevent puffing force resulting from water vaporization. Later, the pellets are dried to below 12% moisture for shelf stability (Frame, 1994). Subsequently, the cooled pellets will be mixed with parboiled rice at the desired weight ratio and tempered to a certain moisture content and introduced to a cake-puffing machine for a final puffing process.

Parboiled rice, sometimes called processed rice or converted rice, is the paddy rice pre-treated by soaking in hot water, pressure steaming and drying prior to milling

(Roger Daniels, 1970). It is usually light golden or amber in color. Parboiling can improve the food value of a regular rice product and help it retain many vitamins found in raw rice. This is because certain soluble nutrients are transferred from the bran and germ into the endosperm through the process, which also helps make grains separate, fluffy and plump (Roger Daniels, 1970).

Many puffing machines are commercially available. A rice cake machine is a type of puffing machine which is used for producing cereal cakes from cereal kernels or a blend of kernels and other additives, such as pellets and flour. It functions under high temperature and high pressure. The control of puffing time and moisture content are also important factors that impact the quality of products.

2.33 Physical and Chemical Changes During Extrusion

Food extrusion is a very complex system involving various reactions that cause physical and chemical changes of food products. After the food material (often solid powder) is fed into the extruder, it is first hydrated with water to form dough. It will then go through the heating barrels where many chemical and physical changes happen. The cooked dough is squeezed through the die in a shape of strand or others (Booth, 1990; Frame, 1994).

Food extrusion is a HTST (high temperature and short time) process which allows for the making of high quality food products (Schuler, 1986; Harper, 1989). Extrusion can be applied for making "third generation products" (semi-, half-, or intermediate food products), such as pellets (Harper, 1981).

Many thermodynamic processes, physical and chemical changes happen during extrusion. Major chemical changes that occur in the barrel of the extruder include starch gelatinization, lipid and starch complex formation, protein denaturation and Maillard reactions (Baianu et al., 1992). Those changes enable the extruded products to obtain unique texture, flavor or color, which could be desired or undesired.

2.34 Processing Factors Affecting Product Attributes During Puffing

"Puffed grain cakes are a simple system to study puffing and texturizing of foods" Huff et al. (1992). The appearance and/or specific volume, textural strength (hardness), color and integrity of the cakes are the quality factors of concern. The specific volume of puffed cakes indicates the degree of expansion when the grains are puffed in the puffing machine (Huff et al., 1992). Color, an important factor that affects the appearance of puffed cakes, can influence consumer acceptance and preference. It can be measured using a colorimeter and described in terms of lightness, yellowness, and redness. The texture of the cakes is usually defined as hardness, or the amount of peak force generated during a breaking test. The integrity of the cakes relates to the degree of fragility, which is another important quality attribute when considering packaging operation and consumer acceptance. It is determined by the percent weight loss after tumbling.

According to previous studies, the main process variables that influence the product attributes mentioned above are tempering moisture content, heating temperature, heating time length, and interactions among these attributes. Other factors that could affect product properties might be the nature of the puffing material (Hsieh et al., 1989; Huff et al., 1992; Orts et al., 2000). Chinnaswamy and Bhattacharya (1984) reported that the puffing ability of parboiled rice is highly related to its amylose content, the higher the amylase, the higher expansion during puffing. Chandrasekhar and Chattopadhyay (1989) mentioned in their report that the kernel shape and protein content had a significant effect on the expansion ratio of puffed rice kernels. Further, the authors pointed out that the degree of starch gelatinization was positively correlated with the expansion ratio of rice kernels as well.

2.341 Tempering Moisture Content

The tempering moisture content affects the specific volume by changing the amount of water vapor, thereby the driving force during puffing process. Therefore, higher moisture content leads to a larger puffing force. However, after the cake is released from the hot puffing mold, the rapid drop in temperature, caused by vaporization atmosphere, may cause the cake to shrink before its volume is completely set. Another affecting factor is the type of cakes because different grains of cake respond differently to the change in tempering moisture. Therefore, for different cakes, the greatest specific volume may occur at different tempering moistures.

The effect of moisture on color also varies with cake type. For rice cakes, Huff et al. (1992) reported a correlation between lightness and specific volume under different moisture level. Rice cakes with a lower specific volume generally have a lighter or whiter color due to a lower expansion of the rice kernels.

Water affects the texture or hardness of the cakes by plasticizing and softening the starch and protein matrix, which are the key factors in the mechanical strength of the products (Katz and Labuza, 1981). For rice cakes, Hsieh et al. (1990) reported that the peak force of breaking the cakes reached a highest value of 0.65 when the water activity changed from 0.44 to 0.84.

For the integrity attribute of the cakes, Huff et al. (1992) reported that when increasing the moisture from 12% to 14%, the percent weight loss of medium-grain rice cakes was reduced significantly from 56% to 34%. But higher moisture content did not cause a significant change in percent weight loss. Further, for long-grain rice cakes, the moisture did not have a significant effect on the cake integrity at all levels tested.

2.342 Heating Temperature and Heating Time

The heating process influences specific volume, color, and texture by affecting the evaporation of water in the cereal kernels and the melting of the kernels. Water vapor is the driving force of kernel expansion and the extent of melting could affect the kernel's elasticity. Therefore, a higher heating temperature and longer heating time increases the cake's expansion or its specific volume.

Heating influences the color of puffed cakes by changing the grain structure and inducing browning reactions. Expansion of rice kernels creates numerous air cells in each of them and those cells render the rice kernels more transparent and, hence, reduce the lightness of the cake. According to Huff et al. (1992), the increase in heating temperature and heating time generally results in decreased lightness value of long- and medium-grain rice cakes. Higher heating temperatures did not affect the yellowness and redness of long-grain cakes but slightly increased the redness of the medium-grain ones (Huff et al., 1992). However, the redness and yellowness of most of the cakes showed an increasing trend when heated for a longer time in Huff's study in 1992.

Raising the temperature or prolonging the heating time affects texture by increasing the bonding strength among the grain kernels and changing their melting condition. Huff et al. (1992) reported that raising the heating temperature from 210^{o}C to 220^{o}C, significantly decreased the percent weight loss after tumbling, or in other words, increased the integrity of the cakes. However, no difference was observed with further increases in temperature. Further, the cake integrity was not affected by the length of heating time for long-grain rice cakes but showed a steady increase at longer time for medium-grain ones.

2.4 Conclusion

Soy foods have a long history of use in Asian countries and are currently receiving more and more attention all over the world. Okara, a by-product of soymilk and tofu manufactures, is a cheap and rich source of protein and dietary fiber and, thus, has great potential to be applied in human foods. In the United States, snack foods occupy a large market. Rice cakes are puffed snack foods popular among American consumers due to their distinctive flavor and a healthy image of natural food. Combining okara with traditional rice cakes is a creative idea to produce a novel low-fat, low-calorie high protein, and high fiber content snack food. Extrusion and rice cake puffing are used in our study and tempering moisture content, heating time and heating temperature during puffing process were the factors affecting the attributes of the final products.

CHAPTER 3

MATERIALS AND METHODS

This study is composed of two parts: product development and sensory study. The objective of part I was to determine how the mixed contents and three processing conditions (moisture content, heating temperature and heating time) affected four textural and physical characteristics of the soy/rice cakes.

Sensory acceptance is critical to conclude the product research and development by determining whether or not the targeted consumers will accept the product. Therefore, the objectives of the sensory study were to determine the relationship between sensory measurements and different attributes, compare consumer preference and acceptance between the products with four different mixed components, and verify the application of okara in rice cake production.

3.1 Raw Materials and Pretreatments

The raw materials used in this study included wet okara, provided by Long Life Bean Curd Factory (St. Louis, MO), rice flour and parboiled rice. Upon receipt, the okara was frozen and maintained at -18^{o}C until used. After thawing at room temperature, the okara was dried in an oven (DN97/98, Hobart, Troy, OH) at 65.5^{o}C and the moisture content of the dried okara was determined by a moisture balance (CSC Scientific Co., Inc., Fairfax, VA). The proximate compositions of parboiled rice, rice flour and dried okara are shown in Table 3.1.

Table 3.1. Proximate composition of parboiled rice and rice flour[1].

Component	Parboiled rice w/w%	Rice flour w/w%	Dried okara w/w%
Crude protein	8.16	5.95	36.60
Crude fat	0.62	1.42	14.10
Ash	1.03	0.61	2.90
Carbohydrate	79.15	80.13	34.60
Moisture	10.82	11.89	11.80

[1] w/w%=g per 100g of sample

3.2 Soy/Rice Cake Production

3.21 Grinding and Blending

Dried okara was pulverized using a grinder (Model SAS06, The Fitzpatrick Company, Elmhurst, IL) with a screening size of 0.093 mm at 24.50 rpm. Subsequently, the grinded okara was mixed with rice flour at a ratio of 3:2 (w/w) using a liquid-solids blender (Patterson-Kelly Co., Model LB-10665, East Stroudsburg, PA) at 24 rpm for 10 min at room temperature. The mixture was stored in a sealed container at room temperature.

3.22 Extrusion

In this study, okara pellets were made by extrusion, a process that heated and pressurized the blend of okara and rice flour until the dusty-like material reached a plastic gel condition. The blended mixture was extruded into strands and pellets were made by cutting the heated strands into small shapes.

An APV Baker MPF 50/25 intermeshing, co-rotating twin-screw extruder (APV Baker, Inc., Grand Rapids, MI) was used for extrusion processing. A volumetric feeder (Model T-35, K-Tron Corp., Pitman, NJ) was used to feed the material into the extruder. A K-Tron 6300 controller (K-Tron Corp., Pitman, NJ) controlled the feeding rate. The extruder barrel was divided into nine zones with the location of the feed port being changeable according to need. In this study, zones 1, 2 and 3 were closed without any heating or cooling, zones 4, 5, and 6 were used for heating at temperatures of 54.4, 60, and 65.6^{o}C, respectively, and zones 7, 8, and 9 were used for maximum cooling. Thermocouple sensors (Single Loop Controller Type 820, Eurotherm, Reston, VA) were used to monitor barrel temperatures and product temperature at the die. For a smoother output, a Teflon die plate with two round openings (diameter, 3.18 mm) was used in this study. A pressure transducer (Dynisco, Inc., Norwood, MA) was used at the die area to monitor the die pressure. A PC-AT/XT computer (Northgate, Plymouth, MN) was used for data recording. The screw configuration used is given in Table 3.2.

After the power was turned on, the extruder barrel zones were gradually heated to the pre-set temperatures. As the blend of okara and rice flour was slowly fed into it, water was slowly injected into the extruder. Both the blend and water feed rate were gradually increased to their pre-set rates. About 15 min were needed for the warming up period.

The okara-rice flour blend extrusion conditions are specified in Table 3.2. When the desired translucent strands exited stably, they were cut and collected at the die opening. The strands were cut into short pellets using a pair of scissors at about every 0.8

Table 3.2 Extrusion Condition Records

Screw revolution (rpm)	Torque (%)	Die pressure (psi)	Die-T (^{o}C)	Cutter length (mm)	Feed kg/h	Water kg/h
122.4	12.5	123.2	97.1	100.6	39.5	5.7

Product 9 (^{o}C)	Barrel 9 (^{o}C)	Product 8 (^{o}C)	Barrel 8 (^{o}C)	Product 7 (^{o}C)
112.5	134.5	103.4	126.6	60.0
Barrel 7 (^{o}C)	Product 6 (^{o}C)	Barrel 6 (^{o}C)	Product 5 (^{o}C)	Barrel 5 (^{o}C)
99.3	48.0	76.2	44.6	30.3

cm upon their exit and spread evenly on a tray. To prevent the strands from sticking together, a fan was used to facilitate extrudate cooling at room temperature (23^{o}C).

3.23 Blending and Tempering

The okara-rice flour pellets collected were dried in the oven at 65.5^{o}C, with forced air at room temperature (23^{o}C), until their moisture content was below the puffing moisture condition (14%). After cooling down to room temperature (23^{o}C), the dried pellets were covered with aluminum foil to prevent them from absorbing moisture, and stored at room temperature for later use.

The puffing process was conducted during a five-day period and one batch was puffed each day. Sixteen hours before puffing, the moisture content of the pellets and parboiled rice was checked and the pellets and rice were divided into two groups, one adjusted to 14% moisture and another to 17% moisture (wet basis). The pellets and rice were adjusted separately by adding back water and tempering in the blender at 24 rpm for approximately 30 min. The amount of water needed was calculated using the following equation:

Material Weight x Initial Moisture Content + Water Needed (ml) = Final Moisture Content x [Material Weight + Water Needed (ml)]

3.24 Puffing

A Light Energy Rice Cake Machine (Real Foods Pty Ltd., St. Peters, Australia) shown in Figure 3.1 and 3.2 was used for puffing. The puffing mold consists of three molds: a ring-shaped side piece and upper and lower platens, which could be pneumatically moved up and down to adjust the gap between them. Each of the platens encloses a heater (Hsieh et al., 1989).

After 16 h of tempering, the blend of pellets and parboiled rice was puffed. The rice cake machine was turned on to warm up until the temperature of both the up and bottom platens reached a pre-set value and remained stable. One mixed ratio of pellets and parboiled rice was puffed per day. Puffing was conducted at three temperatures: 221, 232, and 243^{o}C, sequenced from low to high and at three heating times: 4, 5 and 6 s, sequenced from short to long period. The mixture was fed into the storage hopper of the rice cake machine and the soy/rice cakes were puffed and released. The first three puffed cakes were discarded for each temperature change and about 25 cakes were collected per replicate. The cakes were picked by hands and gently placed on trays to prevent any cracking or bruising. After cooling down at room temperature (23^{o}C), the soy/rice cakes were placed into polyethylene bags and sealed for later analyses.

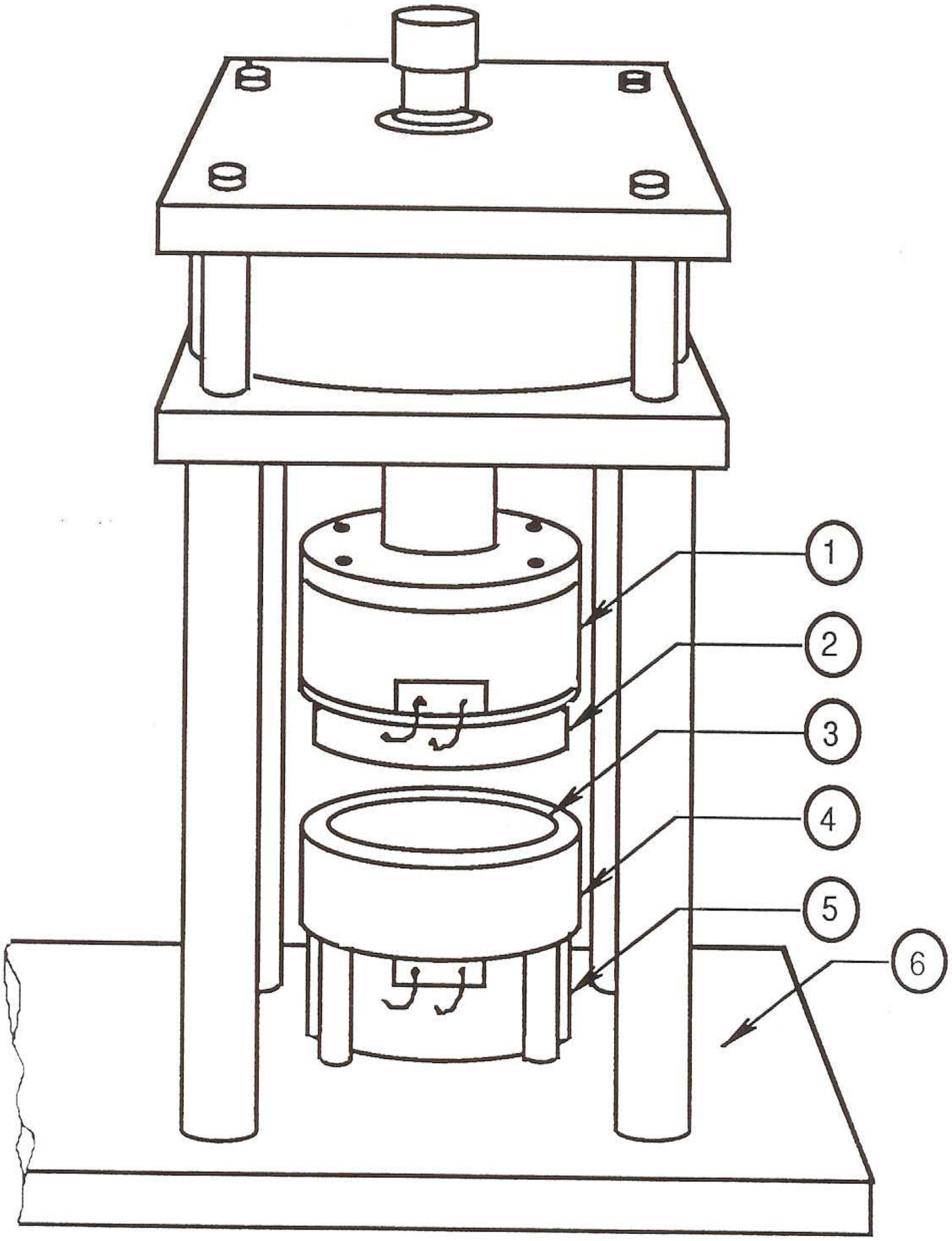


Figure 3.1. Puffing parts of Lite Energy rice cake machine. (1) insulation block; (2) upper platen; (3) lower platen; (4) ring mold; (5) insulation block; (6)base plate (Hsieh et al., 1989).

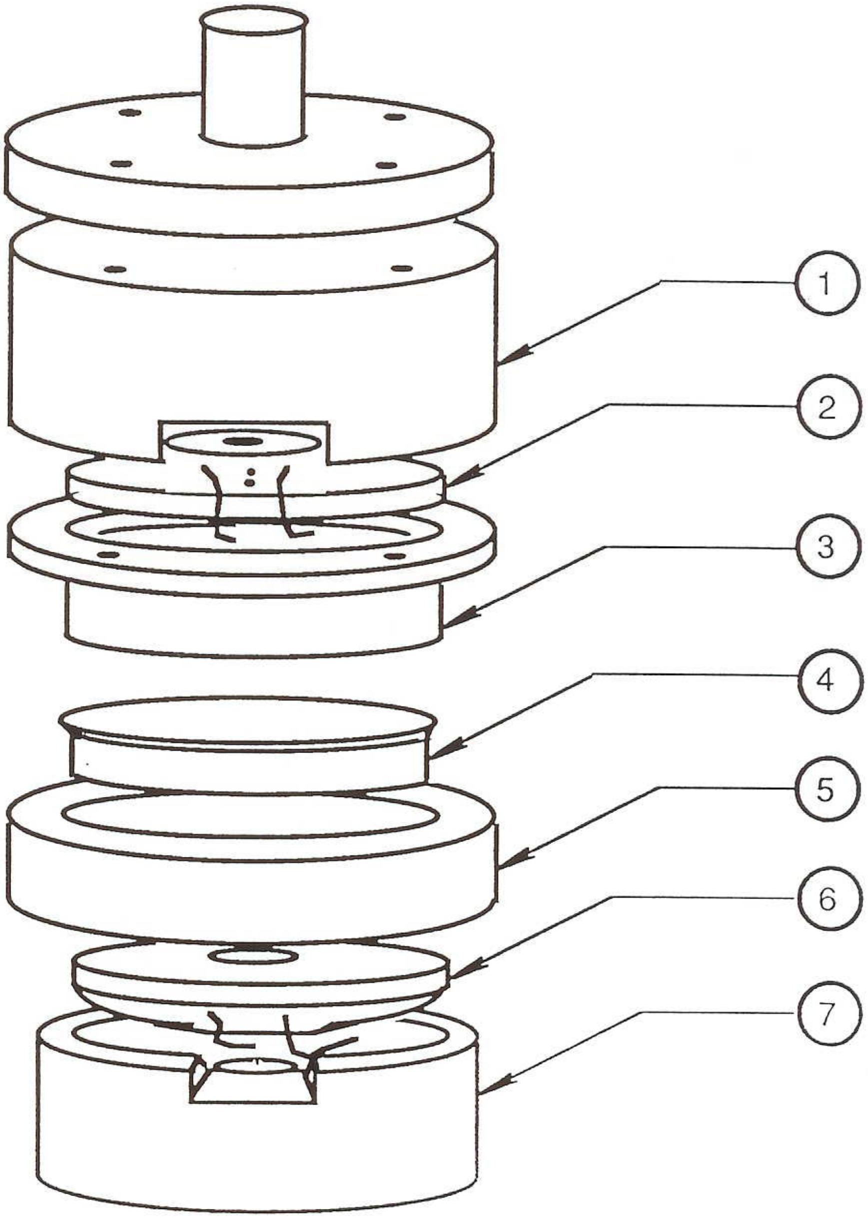


Figure 3.2. **Puffing mold assembly of Lite Energy rice cake machine. (1) insulation block; (2) upper platen heater; (3) upper platen; (4) lower platen; (5) ring mold; (6) lower platen heater; (7) insulation block (Hsieh et al., 1989).**

3.3 Experimental Design

A split plot design, arranged as a 4 x 2 x 3 x 3 factorial with two replications was used in this study. The materials being processed were blends of okara-rice flour pellets and parboiled rice. The main plot was the mixing ratio of puffing materials, which were the pellets and rice blended in four batches, with one batch per day with a specific ratio of 0/100, 90/10, 70/30, and 40/60 (w/w), respectively. The subplot consisted of moisture content (14 and 17%), heating temperatures (221, 232, 243^{o}C) and 3 heating time periods (4, 5, 6 s). There were a total of 72 treatments in this experiment.

3.4 Product Evaluation

The okara/rice cakes were evaluated for specific volume (SPV), texture, color, and percent weight loss (integrity) after tumbling.

3.41 Specific Volume (SPV)

The specific volume of a cake is defined as the ratio of the cake volume over cake weight (Park, 1976). It is an indication of the degree of cake expansion. The rapeseed replacement method of Hsieh et al., 1989 was followed to obtain the cake volume. The method works as follows: a cake with a known weight was placed in a container with a known volume; rapeseed with a known density was filled until all the space around the cake in the container was occupied with rapeseed. The total weight of the filled container was recorded. The cake volume is the volume difference of container and rapeseed. The rapeseed volume is obtained by dividing its weight, which is the weight difference of the full container and cake, by its density. When tested, the rapeseed was filled up in three increments, first to half of the cake, secondly the whole cake, and lastly, to the whole container. For each filling, the container was tapped three times on each side to pack down the rapeseed.

For each treatment, five cakes were randomly selected and tested. The cake weight and the weight of the filled container were recorded. Finally, the specific volume was calculated.

3.42 Hardness

The hardness value depicts the texture perception of the consumer at first bite. It was measured using a TA.HDi Texture Analyzer (Texture Technologies Corp., Scarsdale, NY). The hardness of a cake was defined as the maximum force (g) needed to break it with the blade.

During testing, a cake was placed on two parallel support bars, 60 mm apart. A flat-edged blade (70 × 2.5 mm) was fixed on the crosshead of the machine in a way parallel to the support bars and set to an initial height of 18.0 cm away from the bars and a speed of 1 mm/sec. When the blade cracked the cake, a peak curve recording the forces in the process was shown and peak force was reported as the hardness of the cake. In this study, Newton was used for the force unit. For each treatment, ten cakes were randomly selected and tested.

3.43 Color

The color of the soy/rice cakes was measured using a Hunter D25L Colorimeter (Hunter Associates Lab., Reston, VA). The L, a, b reading styles were recorded for this research. “L” stands for lightness with its value ranging from 0 (darkness) to 100 (lightness), “a” stands for redness when readings are positive and greenness when readings are negative, and “b” stands for yellowness at positive readings and blueness at negative readings. For each treatment, three cakes were randomly selected and tested. Three readings were recorded per cake, which was done by rotating the cake 120 degrees.

3.44 Integrity (Weight Loss After Tumbling)

Integrity measures the fragility of the soy/rice cakes or how easily a cake would fall apart. This measurement could be used to predict the breakage degree during cake distribution and transportation. Integrity was defined as percent weight loss after tumbling.

The tumbling test was conducted using a device that has six cylinders mounted on a rotating axis as shown in Figure 3.3 (Huff et al., 1992). The cylinders were cut from a piece of PVC pipe (15.24cm diameter) and were 30.48 cm long. One end of each cylinder was sealed with 1.91 cm plywood, and the other end had screw-on caps. All six cylinders tumbled from end-to-end simultaneously.

During the test, the cakes were first weighed, then gently placed into the cylinders with each cylinder holding only one cake. The cylinders were covered with their caps. A tumbling speed of 30 rpm and tumbling time of 3 min were chosen for this study. The

largest pieces of the cakes were taken out and weighed after 1 and 3 min of tumbling. Therefore, there were a total of three weight readings. The percent weight loss was calculated using the following equation:

$$\% \text{ weight loss} = [(\text{initial weight} - \text{weight after tumbling})/\text{initial weight}] \times 100$$

Three cakes were selected randomly from each treatment and the average values were reported.

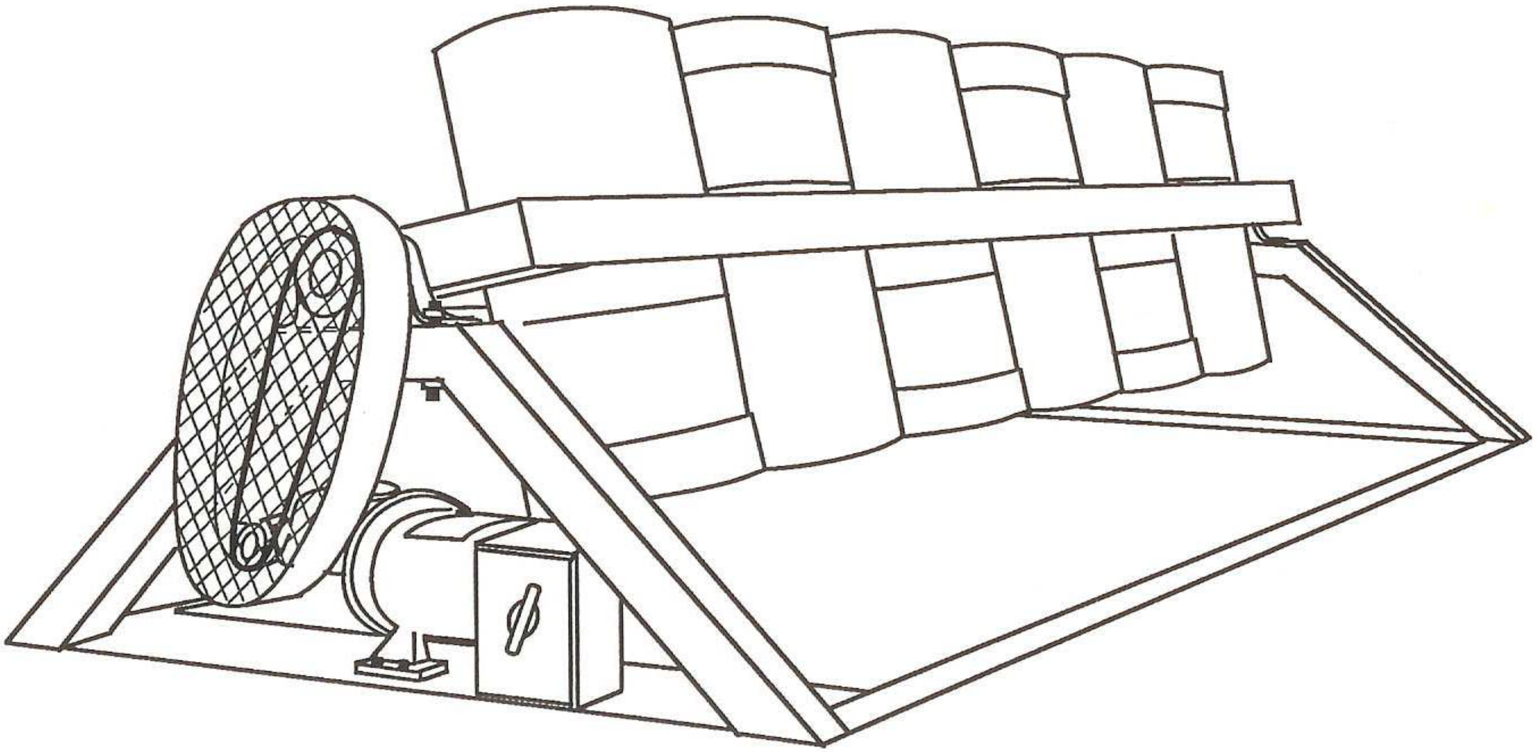


Figure 3.3. Tumbling device for determining % weight loss of grain cakes (Hsieh et al., 1992)

3.45 Data Analysis

All data were analyzed using the Statistical Analysis System (SAS 8.2, 2001). Significant differences in each attribute (specific volume, hardness, lightness, redness, yellowness and integrity) among treatments were established using the General Linear Model Procedure of SAS. The Analysis of Variance results for each cake attribute was reported to study the main effects and interactions of the four processing factors: pellet-rice ratio, moisture content, heating temperature and heating time. The data were analyzed as a split plot design, in which the main plot was pellet-rice ratio (90/10, 70/30, 40/60 and 0/100 (w/w)). The subplot consisted of moisture content (14 and 17%), heating temperatures (221, 232, 243^{o}C), three heating time periods (4, 5, 6 s) and all possible interactions of the subplot effects and the main plot effect. Besides, SAS was also used to establish the second-order polynomial regression equation to predict the effect of the four variables on the product attributes. According to the equation, Sigmaplot 9.0 computer software program was used to draw 3-D plots to have a visual interpretation of the prediction.

3.5 Consumer Test

A ranking test was conducted to determine consumer preference and a hedonic test was conducted to determine consumer acceptance and four other hedonic attributes for each of the four prototypes. The Compusense 5® computer software program version 4.6 (Compusense Inc. Ontario, Canada) was used to generate the 3-digit random numbers for coding the test samples, the sample serving sequences for each judge, give evaluation directions to the judges and to analyze the result of the sensory study.

3.51 Sample Preparation

Four sample groups were prepared. Each was puffed under different processing conditions (moisture content, heating temperature and heating time) (Table 3.3), which were selected according to the results from the preliminary study. The objective was to obtain samples with similar and comparable textural and physical attributes so that preference and acceptance tests would be conducted fairly among all the four sample groups. The attributes of each mixture puffed under the selected puffing conditions are shown in Table 3.4.

All soy/rice cake samples were puffed 7 days before the sensory test and stored in 23°C before used. The cakes were spread on trays and salted with 20% saline water using a 125ml Thin Layer Chromatography sprayer (Diameter × Height: 29/16 × 8 1/16 inch; $\overline{\$}$Joints: 24/40), with low pressure air (5/PSI), to spray a mist on the surface of the cakes. To uniformly cover the cakes with salt, the solution was dyed with red food color (McCormick & Co., Hunt Valley, MD) so that the amount of salt sprayed on the cakes was visible and could be adjusted accordingly. Salted cakes were dried in the oven at 65.5°C for 1.5 min to maintain a crispy texture. After that, all samples were cut into approximately 50 × 50 × 50 triangles, placed in 16.5 cm × 14.9 cm zipper seal sandwich bags, and stored no longer than 36 h until used.

Table 3.3. Puffing conditions for four mixtures of okara pellets and parboiled rice in the sensory study.

Pellet/ Rice (w/w)	Moisture (%)	Temp (^{o}C)	Time (s)
0/100	17	221	4
90/10	17	243	4
70/30	17	243	6
40/60	17	232	4

Table 3.4. Values of attributes of each mixture puffed under the selected puffing conditions shown in Table 3.3.

Pellet/Rice (w/w)	Hardness (g)	SPV (cm3/g)	Lightness	Redness	Yellowness	Weight loss after 3min tumbling (%)
0/100	1097.52	5.45	80.45	0.47	11.17	13.93
90/10	1094.00	5.26	72.00	7.67	26.74	2.52
70/30	1251.39	6.63	75.50	7.56	21.37	5.26
40/60	1292.96	5.23	69.76	3.98	19.65	9.15

3.52 Recruitment of Consumer Judges

One hundred and one consumer judges were recruited by distributing flyers around the campus of University of Missouri-Columbia. The sensory study was approved by the University of Missouri Human Subject Institutional Review Board. Various populations with different age, major and nationality were involved in this sensory study. The screening criteria included: must be 18 years old or older, not pregnant and not allergic to soy. As compensation, every judge was rewarded with a Buck's Ice Cream coupon.

3.53 Ranking Test (Preference Test)

A ranking test was conducted to evaluate consumer preference of four soy/rice cakes with different blending ratios [90/10, 70/30, 40/60 and 0/100 (w/w)]. The evaluations were performed in an isolated room illuminated with five 50-watt fluorescent red lights. A printed evaluation instruction was attached next to each seat so the judges have access to it whenever needed. Baby carrots used for cleaning the aftertaste in the mouth, water, and spit cups were provided to each judge. After signing the consent form, one consumer judge was seated in front of a computer installed with Compusense 5® software, and the four treatments (prototypes) in the zipped bags coded with 3-digit random numbers were served one at a time. The consumer judges were instructed to taste all the four samples before providing their evaluation and to clean their mouths with the carrots and water between samples. The ranking test was presented at the first opportunity in the session and it required the judges to rank the samples from the ones they liked the most to those they liked the least.

3.54 Hedonic Test (Acceptance Test)

A consumer hedonic testing was conducted to determine the acceptance and likeness of four other attributes of the prototypes. It was tested after, but, in the same session of the ranking test and was performed using the same procedure and conditions as were used in the ranking section (refer to 3.53 Ranking Test). Five attributes of interest included Overall Likeness, Appearance, Mouthfeel, Texture and Flavor. After completing the ranking test, the judges were required to taste the samples again in an order determined by Compusense 5®. Then, they were instructed by the computer to rate the samples in terms of their liking or disliking intensities of the samples by checking on a 9-point hedonic scale, with “0” representing “dislike extremely” and “9” “like extremely”.

3.54 Data Analysis for Sensory Study

For the preference ranking test, Friedman’s test was used to evaluate significant differences in the ranking test (Gacula and Singh, 1984). Friedman’s test is the nonparametric equivalent to the two-way analysis of variance without interaction. Its test equation is based on χ^2 distribution:

$$\chi^2 = 12/[N(K)(K+1)] * \sum(T_k)^2 - [3(N)(K+1)]$$

Here K = number of samples; N = number of panelists; T_k = rank totals and the degree of freedom for χ^2 = (K-1). Once the χ^2 test was significant, the comparison of rank total separation was done to determine which samples differed in preference from one another using “least significant ranked difference” or LSRD. The LSRD equation is:

$$LSRD = t * [N*K*(K+1)]^{1/2}$$

Here K = number of samples; N = number of panelists; and t is the critical value at $\alpha = 5\%$, and degrees of freedom = ∞.

For the acceptance test, Analysis of Variance (ANOVA) using Statistical Analysis System (SAS 8.2, 2001) was performed on the consumer degree of likeness scores. Mean degree of likeness scores for the four soy/rice cake samples were compared using Fisher’s least significant difference (LSD). The main effects were consumer and soy/rice cake.

For the relationship between sensory and instrumental data, a Principle Component Analysis (PCA) was performed in this study using SAS (SAS 8.2, 2001). (Appendix C) to incorporate instrumental data (specific volume, hardness, color and integrity) and consumer acceptance data. PCA is a multivariate technique used to simplify and/or describe the interrelationship between multiple dependent variables and among products (Joliffe, 1986; Tabachnick and Fidell, 1983).

Partial Least Square (PLS) Regression (Martens and Martens, 2001) was used to relate rating of the descriptors (independent/predictor variables) to consumers' hedonic scores (dependent variables). The PLS was conducted using SAS (SAS 8.2, 2001). (Appendix C). The difference between PCA and PLS is PCA is used to figure out the relationship between consumer data and instrumental data and PLS is a predictive tool to understand the trend according to consumer data and instrumental data.

CHAPTER 4

RESULTS AND DISCUSSION

Totally 72 treatments of puffed soy/rice cakes were made. Figure 4.1 shows the four mainly soy/rice cakes with different okara pellet/rice ratios. The cakes containing okara had a darker color, a savory cooked flavor and a more crispy texture compared to the control. Besides, no beany flavor was detected in the soy/rice cakes. The products were evaluated in their specific volume, texture (hardness), lightness, redness, yellowness and integrity (percent weight loss after tumbling, 3min). Significant differences among treatments were studied and the effects of processing factors on the quality of the cakes were also discussed in this chapter

Figure 4.1 Puffed Soy/rice cakes with different okara pellet contents

0% okara pellet soy/rice cake

40% okara pellet soy/rice cake

70% okara pellet soy/rice cake

90% okara pellet soy/rice cake

4.1 Specific Volume

The average specific volume of five randomly selected soy/rice cakes produced under each combination of okara pellet content, moisture content, heating temperature and heating time is presented in Table 4.1. Analysis of variance using the GLM procedure of SAS™ indicated that the four variables and most of their interactions had significant effects on specific volume ($P \leq 0.05$) (Appendix B.1), except for the temp*time, ms*temp*time and okara*ms*temp*time (temp: heating temperature, time: heating time, ms: tempered moisture, and okara: okara pellet content) interactions. Therefore, any change in the four processing factors could cause a significant change of the specific volume of the puffed cakes. Generally speaking, raising the puffing temperature, puffing time and moisture content, and decreasing the okara pellet content increased the specific volume, which is visually desirable. Similar results regarding the effect of puffing temperature, puffing time and moisture on the specific volume had been reported by Huff et al., (1992) for medium-grain rice cake, Fan (1997) for wheat cakes, Chen (1998) for sorghum cakes and Zhuang (2003) for potato cakes. The second-order polynomial regression equation of the four variables is as follows:

$$\boldsymbol{V}= 116.42 + 2.86 \times 10^{-1}\,\mathbf{X_1} + 8.32 \times 10^{-4}\mathbf{X_1} \times \mathbf{X_1} - 4.16\,\mathbf{X_2} + 2.77 \times 10^{-3}\mathbf{X_1} \times \mathbf{X_2} - 9.05 \times 10^{-1}\mathbf{X_3} + 1.88 \times 10^{-3}\mathbf{X_3} \times \mathbf{X_3} - 2.10 \times 10^{-3}\mathbf{X_1} \times \mathbf{X_3} + 1.84 \times 10^{-2}\mathbf{X_2} \times \mathbf{X_3} + 3.60 \times 10^{-3}\mathbf{X_1} \times \mathbf{X_2}$$

Here V is the specific volume (cm^3/g) $\mathbf{X_1}$, okara pellet content (%) $\mathbf{X_2}$, moisture content (%) $\mathbf{X_3}$, heating temperature (^{o}C) and $\mathbf{X_4}$, heating time (s). This equation was also used to draw 3-D plots to study the effect of the four variables on product quality.

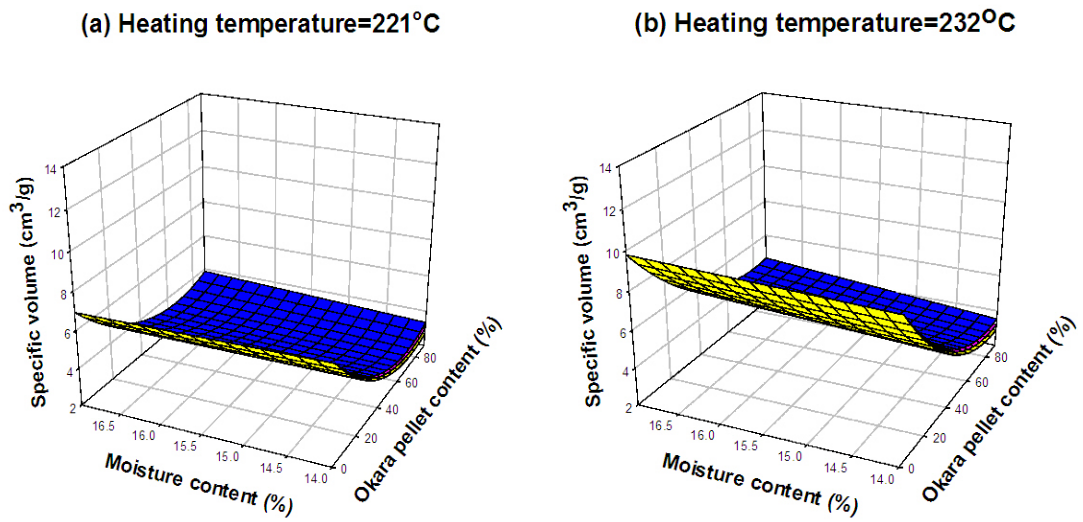
Table 4.1. Specific volume of puffed soy/rice cakes produced under different processing conditions (cm^3/g).

Heating temperature (°C)	Heating time (s)	Okara pellet content (%) and moisture content (%)							
		0 14	0 17	40 14	40 17	70 14	70 17	90 14	90 17
221	4	7.33	5.45	3.74	2.81	1.66	3.39	2.96	3.64
	5	7.88	6.58	3.02	4.35	1.95	3.28	3.48	3.03
	6	8.23	7.44	3.39	4.44	2.53	3.72	4.15	3.40
232	4	9.04	8.05	5.27	5.23	3.43	4.97	2.01	3.62
	5	9.32	9.85	4.84	5.78	3.37	4.71	3.16	4.05
	6	9.74	10.52	5.34	6.43	3.58	5.49	3.30	4.57
243	4	10.91	12.10	6.54	7.21	4.92	6.54	3.67	5.26
	5	11.86	13.87	6.24	7.22	4.77	6.37	3.76	5.17
	6	13.11	15.12	6.92	7.49	5.37	6.63	4.24	5.19

4.11 Effects of Okara and Moisture Content

The effects of okara and moisture content on specific volume are shown in Figure 4.2, in which the plots were drawn according to the equation listed above. Okara pellet content and moisture content had significant effects on the specific volume of the puffed soy/rice cakes ($P \leq 0.05$). The specific volume of the puffed soy/rice cake reached the highest level at an okara pellet content of 0% and a moisture content of 17% (9.71 cm^3/g). When the okara pellet content was raised from 0% to 90%, the average specific volume decreased from 9.80 to 3.81 cm^3/g. When the moisture content was raised from 14% to 17%, the specific volume increased from 5.42 to 6.19 cm^3/g.

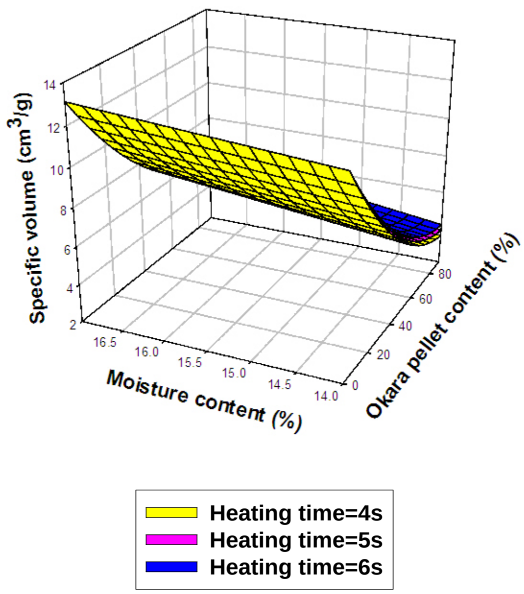
Figure 4.2 **Effects of okara pellet content and moisture content on the specific volume (cm^3/g) of puffed soy/rice cakes at heating temperatures of 221°C, 232°C, 243°C and at a heating time of 5 s.**



(a) Heating temperature=221°C

(b) Heating temperature=232°C

(c) Heating temperature=243°C



The plots of specific volume versus okara pellet content and moisture content at heating temperatures of 221°C, 232°C and 243°C and heating times of 4, 5 and 6 s are shown on Figure 4.2. These plots show that the okara pellet content influenced specific volume more significantly than did the moisture content. Increasing okara content led to decreased specific volume in all three heating temperatures. Though the effect of moisture content was significant ($P \leq 0.05$) in ANOVA result, it was much less important compared with okara content according to the Figure 4.2. Generally, increasing moisture content increased specific volume.

Lower okara pellet content led to a higher specific volume of the cakes. This may indicate that okara pellets have lower elasticity and plasticity and therefore give smaller expansion ratio than rice kernels. Okara is a fibrous material. In earlier studies, high levels of fiber contributed to compact, tough, and undesirable texture because of low radial expansions (Breen et al., 1997, Anderson et al., 1981, Lawton et al., 1972). Park (1976) proposed that the puffing phenomena results from the vaporization of superheated water and the flash–off of vapor expands the starchy material, resulting in a sponge-like structure. The higher the okara pellet content, the less starchy the material, resulting in the puffed cakes having a smaller volume.

Raising the moisture content from 14% to 17% increased specific volume of the puffed soy/rice cakes. This is because when superheated, the moisture content in the rice kernels is vaporized and become the puffing force Huff et al. (1992). Thus, the higher the moisture level, the greater the driving force, and, hence, the bigger the expansion.

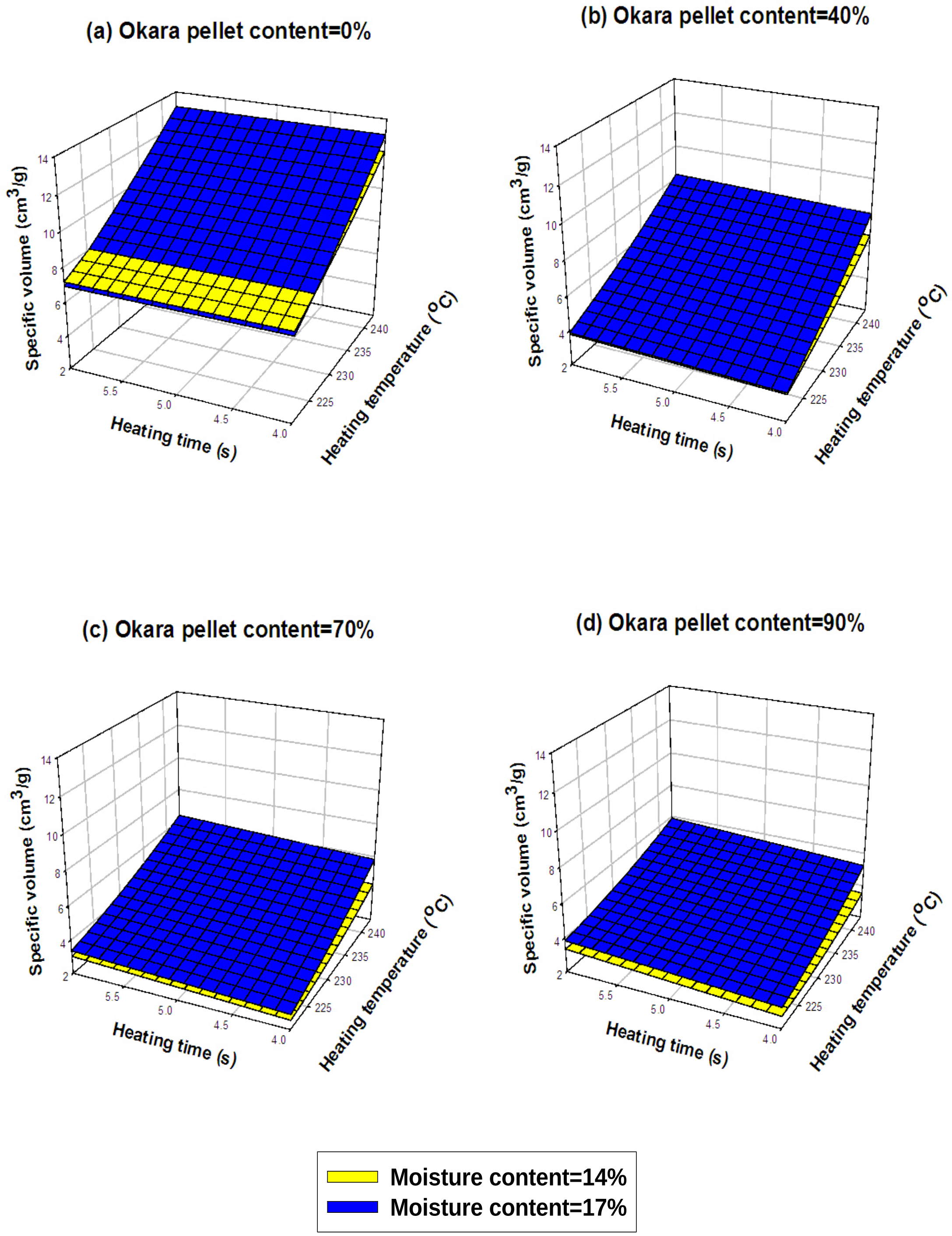
Raising moisture decreased specific volume at lower heating temperature, okara content and shorter heating time and increased volume at higher temperature, okara content and longer time (Table 4.1). Similar results were reported by Kloeppel (1998) and Zhuang (2003). According to Zhuang at lower heating temperature and shorter heating time, excessive moisture could not be converted to vapor; therefore the cakes stuck to the mold of the rice cake machine and when the cakes were released off the mold after puffing, compressions and bites occurred on them

4.12 Effects of Heating Temperature and Heating Time

Figure 4.3 shows the effects of heating temperature and heating time on cake's specific volume. In general, raising heating temperature and heating time significantly increased specific volume of the puffed soy/rice cakes ($P \leq 0.05$). The average specific volume increased from 4.24 to 7.52 cm^3/g when heating temperature increased from 221°C to 243°C; and the volume increased from 5.40 to 6.26 cm^3/g when heating time increased from 4 s to 6 s. The highest specific volume was reached at 243°C and 6s at 8.01 cm^3/g.

Figure 4.3 presents the general trends in specific volume of the soy/rice cakes with different heating temperatures and heating times. In general, the specific volume of the cakes increased with increasing heating temperature and heating time. Similar results were reported by Huff et al. (1992) on long–grain brown rice cakes, Fan (1996) on puffed wheat cakes, Chen (1997) on puffed sorghum cakes, Lee (1999) on puffed barley cakes and Zhuang (2003) on puffed potato cakes. Besides, heating temperature had greater effect on the specific volume at lower okara content. Increasing heating temperature and heating time can accelerate both melting and water evaporation of kernels. The greater the propensity of the kernels to melt, the more elastic they are, and thus, the degree of

Figure 4.3 **Effects of heating temperature and heating time on the specific volume (cm^3/g) of the puffed soy/rice cakes at okara pellet contents of 0%, 40%, 70% and 90% and moisture contents of 14% and 17%.**


(a) Okara pellet content=0%

(b) Okara pellet content=40%

(c) Okara pellet content=70%

(d) Okara pellet content=90%

expansion or the specific volume of the puffed cakes was enhanced. The pressure build up of water evaporation is the driving force during puffing, thus, increasing pressure also leads to greater cake expansion.

4.2 Texture

Texture of the puffed soy/rice cakes in this study was determined by measurement of degree of hardness, which is the maximum peak force generated during the break test. Ten pieces of randomly selected soy/rice cakes from each treatment combination of okara pellet content, moisture content, heating temperature and heating time were tested for hardness and the average values are shown in Table 4.2.

All four factors of okara pellet content, moisture content, heating temperature and heating time, and most of their interactions except ms*time, okara*ms*time and rep(okara) affected the hardness of the soy/rice cakes significantly at a 5% level (Appendix B.2). The regression result of a second-order polynomial equation that describes the hardness as a function of the four variables is:

$$\boldsymbol{H} = -18354.92 + 7.77 \times 10^{1}\,\mathbf{X_1} + 8.13 \times 10^{2}\mathbf{X_2} - 1.439\,\mathbf{X_1} \times \mathbf{X_2} + 8.06\mathbf{X_3} - 2.32 \times 10^{-1}\mathbf{X_1} \times \mathbf{X_3} - 3.25\mathbf{X_2} \times \mathbf{X_3} + 1.14 \times 10^{3}\,\mathbf{X_4} - 4.78\mathbf{X_3} \times \mathbf{X_4}$$

Here H is the hardness (g), $\mathbf{X_1}$, okara pellet content (%), $\mathbf{X_2}$, moisture content (%), $\mathbf{X_3}$ heating temperature (°C), and $\mathbf{X_4}$, heating time (s).

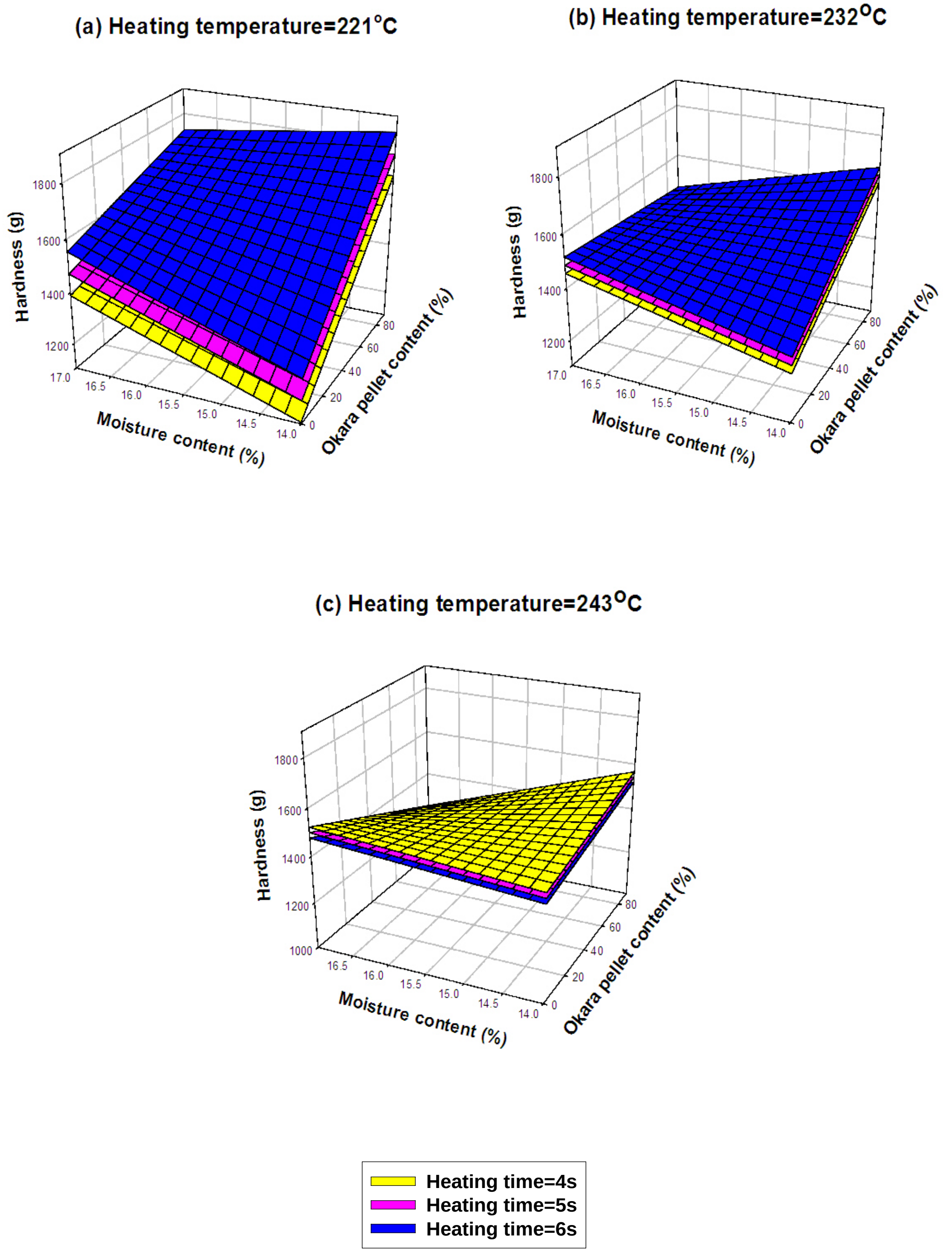
Table 4.2. Hardness of puffed soy/rice cakes produced under different processing conditions (g).

Heating temperature (^{o}C)	Heating time (s)	Okara pellet content (%) and moisture content (%)							
		0 14	0 17	40 14	40 17	70 14	70 17	90 14	90 17
221	4	1126.21	1097.52	1655.75	1778.47	1544.18	1520.90	1294.48	1788.08
	5	1031.15	1331.83	1583.55	1675.92	1461.28	1370.92	1885.89	1640.65
	6	1319.42	1589.52	1761.50	1677.62	1705.38	1485.09	1784.12	1631.75
232	4	1004.60	1536.48	1463.37	1292.96	1569.28	1368.54	1728.59	1344.81
	5	1316.32	1604.59	1403.51	1336.05	1540.21	1683.04	1726.14	1781.66
	6	1470.28	1657.91	1398.14	1450.25	1430.03	1491.27	1757.00	1481.92
243	4	1309.00	1703.87	1453.52	1385.98	1492.70	1371.54	1747.36	1094.88
	5	1594.40	1474.87	1478.42	1406.20	1486.85	1315.05	1570.80	1009.01
	6	1451.38	1301.64	1514.97	1368.76	1347.17	1251.39	1583.33	1204.86

4.21 Effects of Okara and Moisture Content

The effects of okara and moisture content on hardness are shown in Figure 4.4. Analysis of Variance indicated that both okara pellet content and moisture content had significant effects on the hardness of puffed soy/rice cakes ($P \leq 0.05$), with okara pellet content ($P \leq 0.0001$) having more significant effect than moisture content (P = 0.0203). When the okara pellet content was raised from 0% to 90%, or the rice content was decreased from 100% to 10%, the average hardness increased from 1384.50 g to 1558.63 g. Raising moisture content from 14% to 17% decreased the average hardness from 1499.73 g to 1458.49 g.

Figure 4.4 **Effects of okara pellet content and moisture content on the hardness (g) of the puffed soy/rice cakes at heating temperatures of 221°C, 232°C, 243°C, and heating times of 4 and 5 s.**



The highest hardness was reached at 90% okara pellet content and 14% moisture content. Hardness was enhanced when raising moisture content at okara pellet content 0%, which is supported by the report of Bange and Hsieh (1994) on the hardness of yellow corn cakes produced at moistures ranging from 13% to 17% and Kloeppel (1998) on puffed white and yellow corn cakes produced at moistures ranging from 12% to 16%. However, for the 40% okara treatment, no significant difference in hardness were observed between the 14% and 17% moisture treatments; for 70 and 90% okara pellet content increasing the moisture content led to decreased hardness, which is in agreement with the report of Fan (1997), in which raising the moisture content from 14% to 16% resulted in an increase in the hardness of wheat cakes. Besides, okara pellet and moisture content had greater effects on specific volume at lower heating temperature.

According to Fan (1997), Chen (1998) and Miller (1985), two factors affect the hardness of puffed products: the adhesion strength between the cereal kernels and the mechanical strength of each puffed cereal kernel. The mechanical strength of the individual puffed rice kernel was highly related to the thickness of the kernel cell walls. They also relate to the expansion of the kernels, or, in other words, the specific volume of the cakes. A greater expansion resulted in a larger surface area of the rice kernels, and, thus, higher adhesion strength among them. On the other hand, it also resulted in thinner rice cell walls, and, thus, a lower mechanical strength of individual puffed rice kernel. As a result, the soy/rice cakes, puffed under higher moisture content and lower okara content (or higher rice content), had higher specific volume and lower degree of hardness. Therefore, in this study, the mechanical strength of the individual kernel played a major role, which is similarly reported by Fan (1996) on the hardness of puffed wheat cakes and Lee (1999) on the hardness of puffed barley cakes.

4.22 Effects of Heating Temperature and Heating Time

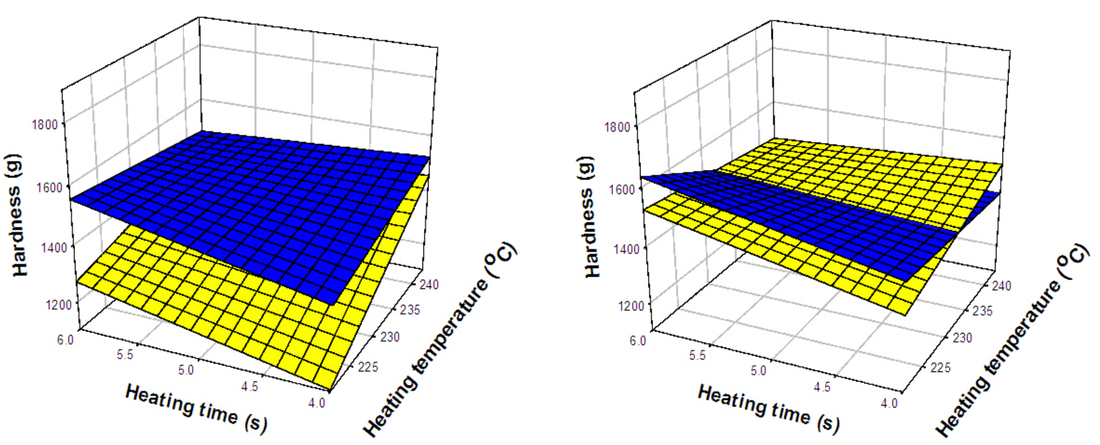
The effects of heating temperature and heating time on hardness are shown in Figure 4.5. Analysis of variance indicated that both factors had significant effects on the hardness of puffed soy/rice cakes ($P \leq 0.05$), with heating temperature ($P \leq 0.0001$) having more significant effect than heating time ($P = 0.0175$). The average value of hardness decreased from 1530.88 g to 1413.25 g, when heating temperature was elevated from 221^{o}C to 243^{o}C, and increased from 1444.71 g to 1504.78 g, when heating time was increased from 4 s to 6 s. This finding is also supported by previous studies on puffed wheat cakes (Fan, 1996) and puffed sorghum cakes (Chen, 1998). According to the P value, the heating temperature played a more important role on influencing the hardness of cakes than the heating time.

According to the explanation in section 4.1.1, the higher the specific volume, the thinner the rice kernel cell wall, and therefore, the lower the mechanical strength of the individual kernel, which leads to a lower hardness of the resulting puffed cakes. Increasing heating temperature led to increased hardness at 0% and 40% okara content and moisture 14% and decreased hardness at 70% and 90% okara pellet content (Figure 4.5). This is probably because lower okara, moisture and heating temperature avoided generating excessive moisture, which led to a bigger volume of the cake. Otherwise, higher heating temperature increased the specific volume, meanwhile lower hardness. Besides, the specific volume of the puffed soy/rice cakes increased steadily with the increase of heating temperature, which resulted lower hardness also.

Figure 4.5 Effects of heating temperature and heating time on the hardness (g) of the puffed soy/rice cakes at okara pellet contents of 0%, 40%, 70% and 90% and moisture contents of 14% and 17%.

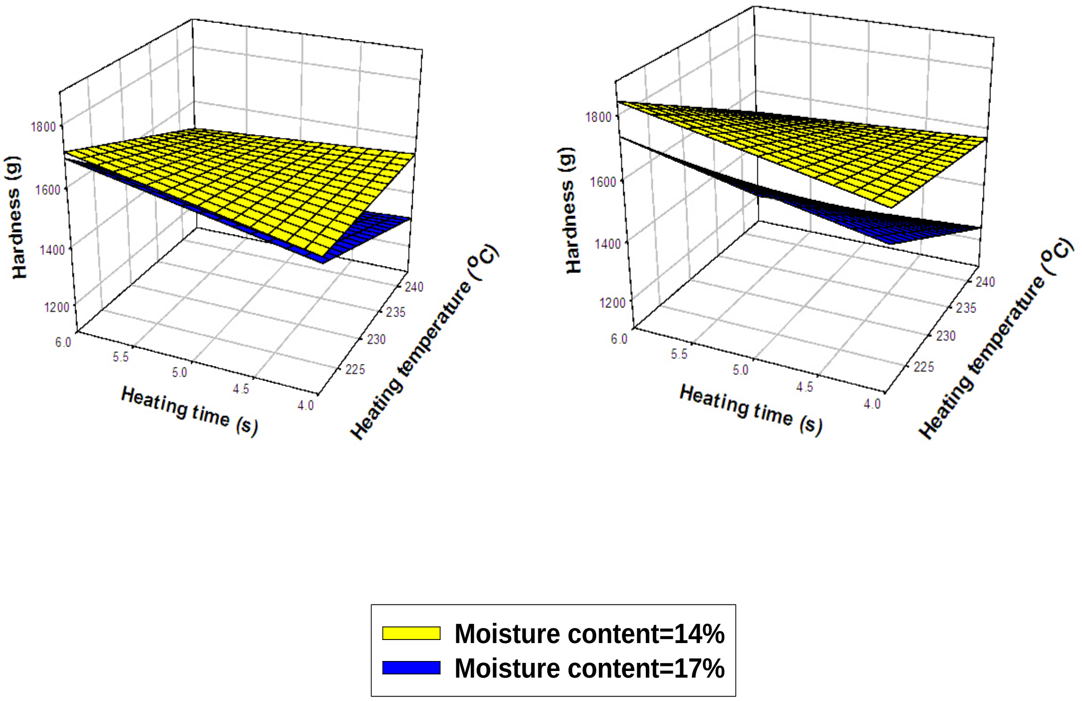
(a) Okara pellet content=0%

(b) Okara pellet content=40%



(c) Okara pellet content=70%

(d) Okara pellet content=90%



4.3 Color

The color of the puffed soy/rice cakes was determined by a Hunter D25L colorimeter (Hunter Associates Lab., Inc., Reston, VA). Color of the cakes was described in terms of lightness (L value), redness (a value) and yellowness (b value). Four randomly selected puffed soy/rice cakes from each treatment were tested for lightness, redness and yellowness, and three readings were taken for each tested cake.

4.31 Lightness

L-value represents the lightness ranging from 0 (darkness) to 100 (brightness). Twelve readings were obtained for one treatment, and the average values for lightness are presented in Table 4.3. Analysis of variance, using the GLM model, showed that the four variables: okara pellet content, moisture content, heating temperature and heating time and their interactions had significant effects on lightness ($P \leq 0.05$) except for ms*temp*time (Appendix B.3). The second-order polynomial regression equation that described the lightness as a function of the four variables is as follows:

$$\boldsymbol{L} = -409.32 + 2.17\times 10^{-3}\mathbf{X_1}\times\mathbf{X_1} + 5.90\times 10^{-3}\mathbf{X_1}\times\mathbf{X_2} + 3.83\mathbf{X_3} - 7.32\times 10^{-3}\mathbf{X_3}\times\mathbf{X_3} - 1.58\times 10^{-3}\mathbf{X_1}\times\mathbf{X_3} + 2.43\mathbf{X_4} - 1.13\times 10^{-2}\mathbf{X_1}\times\mathbf{X_4} - 1.55\times 10^{-1}\mathbf{X_2}\times\mathbf{X_4} - 9.77\times 10^{-2}\mathbf{X_3}\times\mathbf{X_4}$$

Here **L** is the lightness, $\mathbf{X_1}$, okara pellet content (%) $\mathbf{X_2}$, moisture content (%) $\mathbf{X_3}$ heating temperature (^{o}C) and $\mathbf{X_4}$, heating time (s).

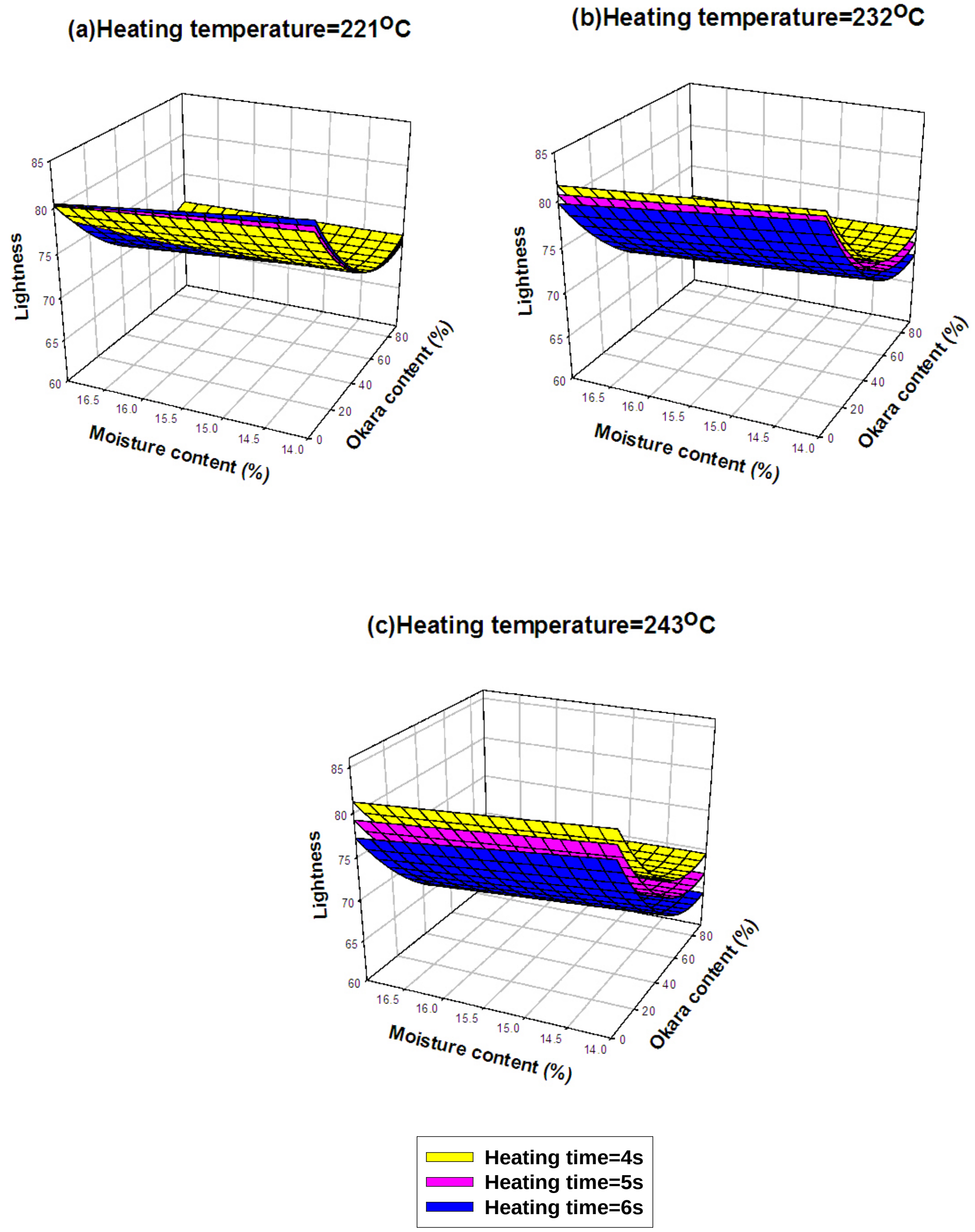
Table 4.3. Lightness of puffed soy/rice cakes produced under different processing conditions.

Heating temperature (^{o}C)	Heating time (s)	Okara pellet content (%) and moisture content (%)							
		0 14	0 17	40 14	40 17	70 14	70 17	90 14	90 17
221	4	81.90	80.45	71.24	72.83	70.48	71.79	70.58	71.13
	5	82.61	81.40	71.46	69.47	71.15	73.09	72.45	69.64
	6	82.54	81.32	72.73	70.49	72.31	70.83	69.44	68.66
232	4	84.39	83.72	73.76	69.76	72.76	69.87	70.61	71.53
	5	81.59	83.09	74.81	68.22	73.00	68.46	68.46	69.39
	6	81.89	81.68	73.12	67.29	72.05	65.96	65.89	65.19
243	4	83.19	80.17	71.26	71.46	72.03	69.01	65.81	72.02
	5	81.61	79.67	70.42	67.95	68.97	65.98	66.03	66.38
	6	79.95	75.49	68.87	65.34	64.64	65.69	64.31	64.20

4.311 Effects of Okara and Moisture Content

The effects of okara pellet content and moisture content on lightness are shown in Figure 4.6. Okara content and moisture content had significant effects on the lightness of puffed soy/rice cakes ($P \leq 0.05$). When okara pellet content decreased from 90% to 0%, the average L-value increased from 68.43 to 81.48. Raising the moisture content from 14% to 17% decreased the average L value from 73.29 to 71.91, which is contrary to the reports by Lee (1999) on puffed barley cakes. Even though the decreases were significant according to ANOVA study, the differences were very small according to Figure 4.6.

Figure 4.6 **Effects of okara pellet content and moisture content on HunterLab *L* value (lightness) of the puffed soy/rice cakes at heating temperatures of 221°C, 232°C, and 243°C, and heating times of 4, 5 and 6 s.**



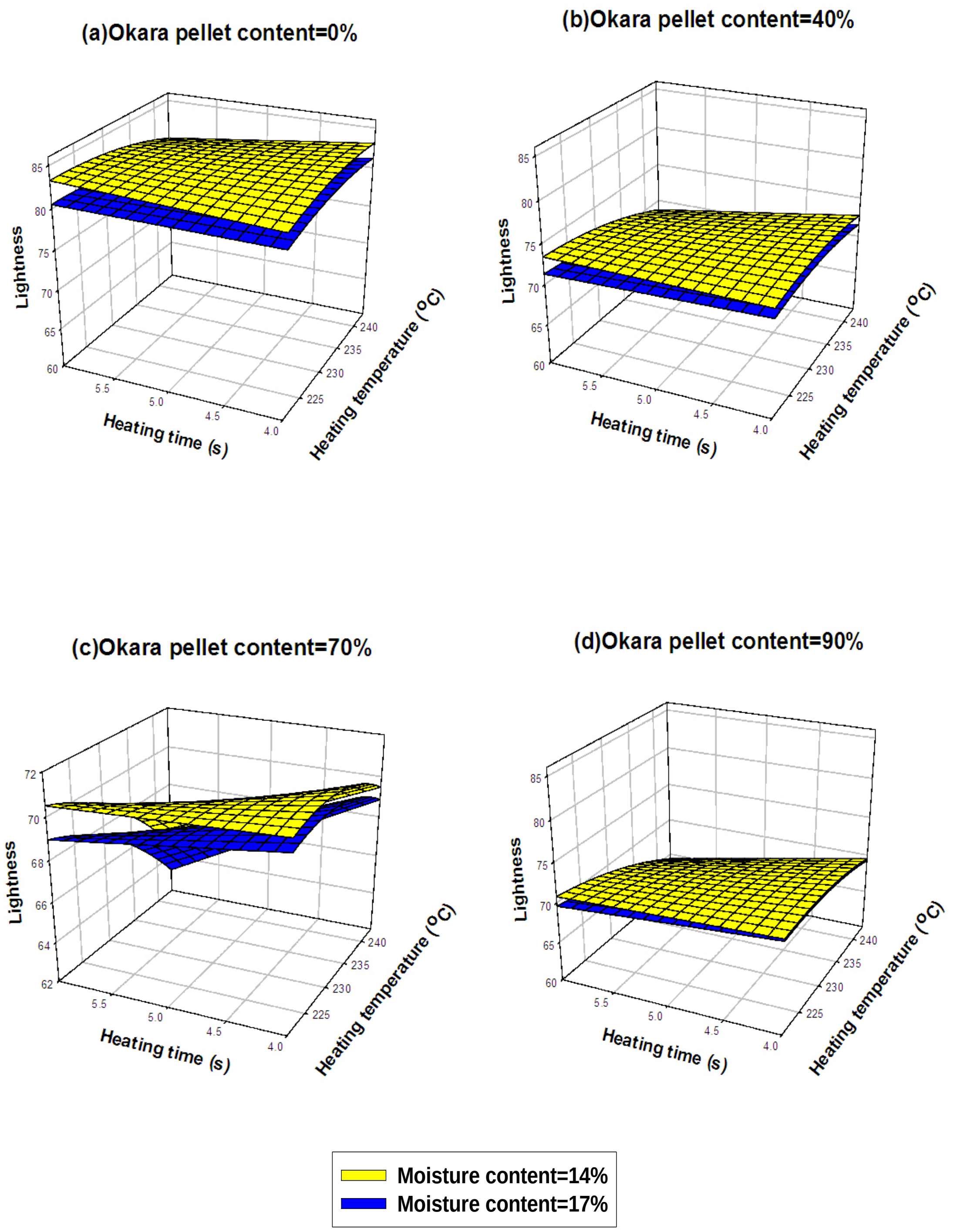
The lightness of puffed soy/rice cakes could be affected by the percentage of the okara pellet, the surface area covered by the rice bran and the browning reaction during the puffing process (Fan et al., 1997). During the puffing process, expanded rice kernels led to a decreased percentage of surface area covered by the bran. Thus, a greater expansion ratio of the kernels, or a bigger specific volume of the puffed cakes resulted in increased lightness of the cakes. Higher okara content led to a decreased specific volume, which could decrease lightness. Also, since okara pellets have a brown color, they contribute more brown color to the puffed cakes than do parboiled rice.

Maillard browning happens during the puffing process because the okara pellets and parboiled rice contain amino acid and reducing sugars, which could react under heat processing conditions and contribute to color formation (Davidek et al., 1990). Many factors, such as moisture content, heating temperature and heating time can affect the Maillard reaction, (Davidek et al., 1990). Intermediate moisture food could accelerate the rate of the browning reaction (Sacchetti, et al., 2004). Raising the moisture content from 14% to 17% led to an increase in the specific volume of the cakes, which, as a result, could have a positive effect on the lightness value. However, the lightness of the puffed soy/rice cakes decreased with the increase in moisture content, which suggested that the browning reaction is more active at a moisture content of 14% than at 17% and might overwhelm the effect of specific volume in this study.

4.312 Effects of Heating Temperature and Heating Time

The effects of heating temperature and heating time on lightness are shown in Figure 4.7. Heating temperature and heating time had significant effects on the lightness of the puffed soy/rice cakes ($P \leq 0.05$). When the heating temperature was raised from

Figure 4.7 Effects of heating temperature and heating time on HunterLab *L* value (lightness) of the puffed soy/rice cakes at okara pellet contents of 0%, 40%, 70% and 90%, and moisture contents of 14% and 17%.



221°C to 243°C, the L value decreased from 73.75 to 70.85. When the heating time was increased from 4s to 6s, the L value decreased from 73.82 to 71.25. Huff et al. (1992) reported similar results on rice cakes, Fan (1996) on wheat cakes, Chen (1997) on sorghum cakes, Lee (1999) on barley cakes, and Zhuang (2003) on potato cakes.

As discussed in 4.311, the lightness of the puffed soy/rice cakes could be affected by the percentage of the surface area covered by the rice bran or the specific volume, and the browning reaction during puffing process. Enhancing the heating temperature and heating time increased the specific volume of the cakes, which, as a result, could increase their lightness. However, it could also accelerate the rate of Maillard browning reactions, which would decrease the lightness. Therefore, in this study, the effect of browning reaction overwhelmed the effect of specific volume.

4.32 Redness

A positive a-value represents redness and a negative a-value represents greenness. Twelve readings were obtained for one treatment and the average values for redness are shown in Table 4.4. Analysis of variance, using the GLM model, showed that the four variables: okara pellet content, moisture content, heating temperature and heating time and most of their interactions, except okara*time*temp and okara*ms*temp*time, had significant effects on redness ($P \leq 0.05$) (Appendix B.4). The second-order polynomial regression equation that described redness as a function of the four variables is as follows:

$$\boldsymbol{a} = -14.63 - 3.06 \times 10^{-4}\mathbf{X_1} \times \mathbf{X_1} - 7.67 \times 10^{-1}\mathbf{X_2} + 3.73 \times 10^{-4}\mathbf{X_1} \times \mathbf{X_3} - 1.46 \times 10^{-1}\mathbf{X_2} \times \mathbf{X_4} + 1.34 \times 10^{-2}\mathbf{X_3} \times \mathbf{X_4}$$

Here **a** is the redness, $\mathbf{X_1}$, okara pellet content (%) $\mathbf{X_2}$, moisture content (%) $\mathbf{X_3}$ heating temperature (°C) and $\mathbf{X_4}$ heating time (s).

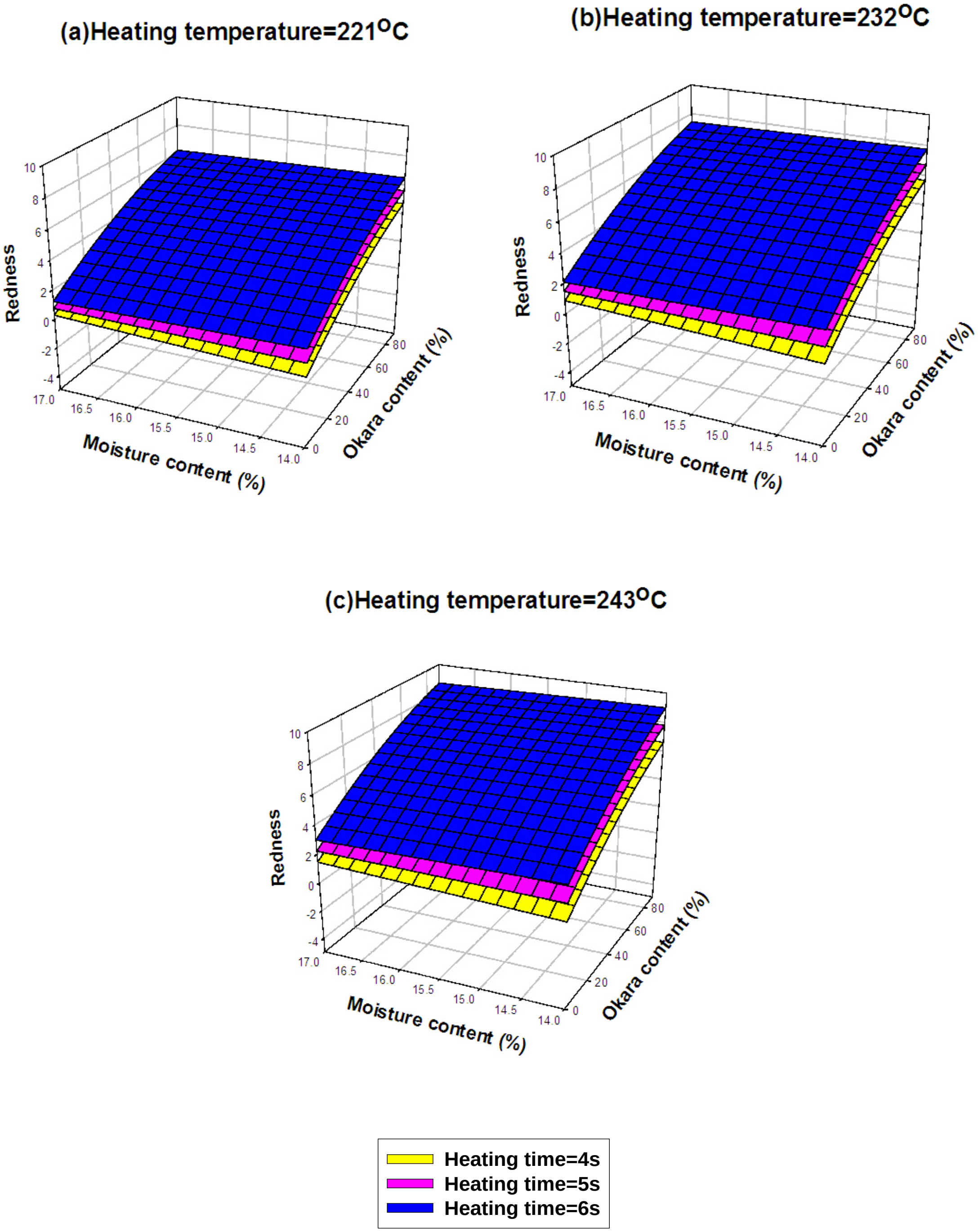
Table 4.4. Redness of puffed soy/rice cakes produced under different processing conditions.

Heating temperature (°C)	Heating time (s)	Okara pellet content (%) and moisture content (%)							
		0 14	0 17	40 14	40 17	70 14	70 17	90 14	90 17
221	4	-0.29	-0.47	3.39	3.81	4.25	3.53	5.10	4.58
	5	0.34	0.12	3.55	4.56	4.99	4.02	5.58	5.15
	6	1.10	1.02	3.59	4.67	5.53	5.07	6.55	6.36
232	4	0.38	0.25	3.38	3.98	4.50	4.51	6.50	5.34
	5	1.92	1.09	3.98	5.43	5.26	6.21	6.91	7.00
	6	2.43	2.11	4.33	5.64	5.48	6.86	8.26	8.71
243	4	1.19	1.60	4.78	4.95	5.41	6.54	7.67	6.78
	5	2.89	1.78	5.59	5.95	6.87	7.16	8.23	8.04
	6	3.68	3.95	5.65	6.45	7.20	7.56	9.15	8.85

4.321 Effects of Okara and Moisture Content

The effects of okara pellet content and moisture content on redness are shown in Figure 4.8. Okara content and moisture content had significant effects on the redness of puffed soy/rice cakes ($P \leq 0.05$). The effect of okara pellet content ($P \leq 0.0001$) is more significant than moisture content (P=0.0352). When the okara pellet content was raised from 0% to 90%, the average a-value increased from 1.39 to 6.93. When the moisture content was raised from 14% to 17%, the average a-value increased from 4.59 to 4.70. Further, even though the effect of the moisture content on redness was significant according to the analysis of variance, Figure 4.8 showed that the trend of redness along

Figure 4.8 Effects of okara pellet content and moisture content on the HunterLab *a* value (redness) of the puffed soy/rice cakes at heating temperatures of 221°C, 232°C, 243°C, and heating times of 4 and 5 s.



the change of moisture content was almost flat, indicating a much smaller influence of moisture compared with that of okara pellet content.

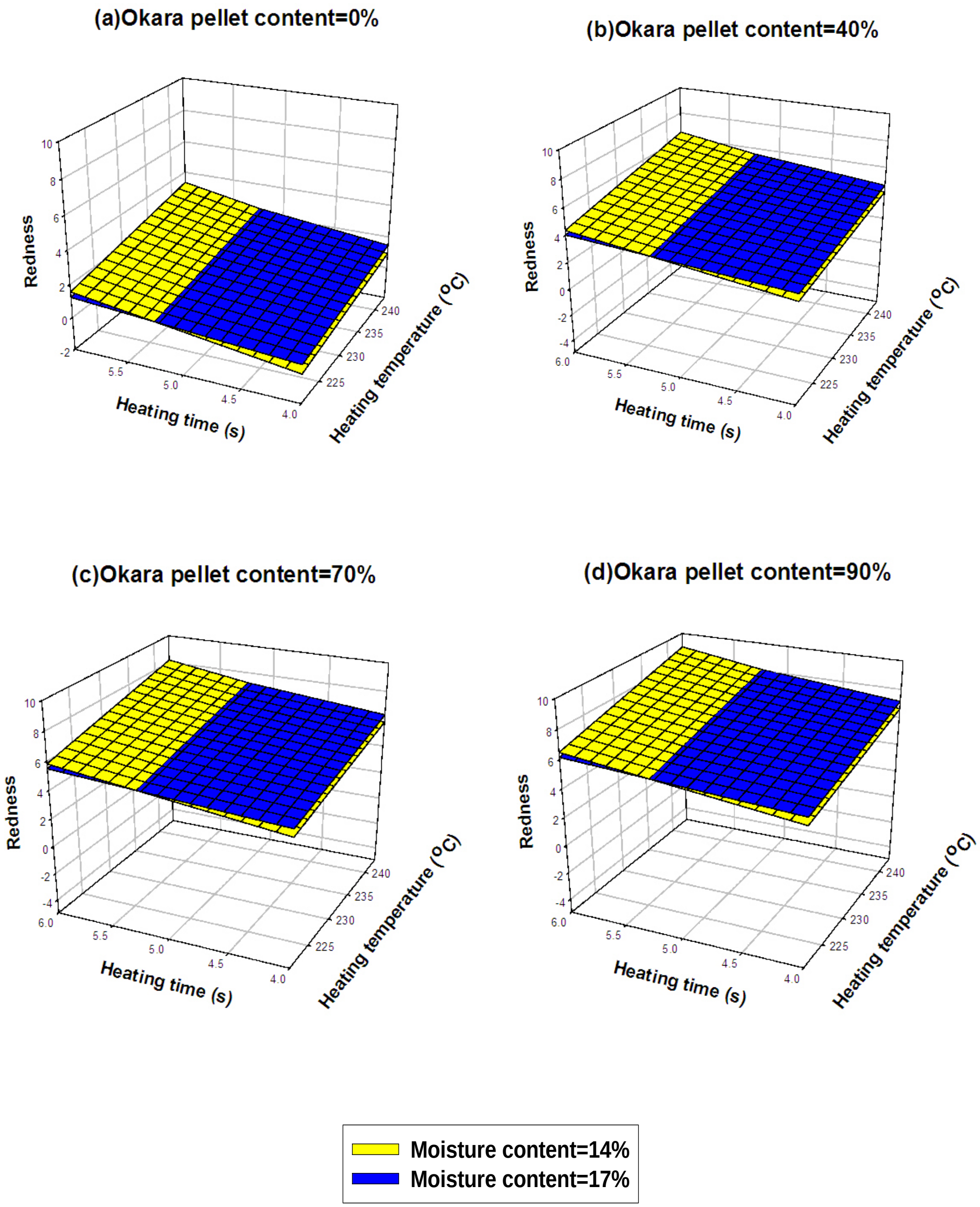
According to the discussion in section 4.311 above, two factors affected the color of puffed cereal cakes: the okara pellet content, the surface area covered by rice bran (specific volume) and the browning reaction that occurs during puffing. Due to the brown color of okara pellet and the contribution of okara content to the decrease in specific volume, the higher the okara pellet content, the more reddish the puffed cakes. Further, the moisture content might affect the color of the cakes by influencing the specific volume and the browning reaction. As discussed in section 4.311, although raising the moisture content from 14% to 17% increased specific volume, 14% moisture content accelerated the Maillard reaction more severely and this effect exceeded the effect of specific volume. Therefore, the cakes processed with 14% moisture content had a more reddish color.

4.322 Effects of Heating Temperature and Heating Time

The effects of heating temperature and heating time on redness are shown in Figure 4.9. Heating temperature and heating time had significant effects on the redness of puffed soy/rice cakes ($P \leq 0.05$). When the heating temperature was raised from 221°C to 243°C, the a-value increased from 3.59 to 5.75. Increasing heating time from 4 s to 6 s increased the a-value from 3.82 to 5.42. This is also in agreement with previous studies (Huff et al., 1992; Fan, 1996; Chen, 1997; Lee, 1999 and Zhuang, 2003).

Higher heating temperature and longer heating time resulted in a bigger specific volume of puffed cakes. This may decrease the redness of the cakes by reducing the surface area covered by the rice kernels while accelerating the browning reaction during

Figure 4.9 Effects of heating temperature and heating time on HunterLab *a* value (lightness) of the puffed soy/rice cakes at okara pellet contents of 0%, 40%, 70% and 90%, and moisture contents of 14% and 17%.



the puffing process, which made the okara pellets appear more scorched and reddish. As discussed in 4.312, the effect of browning reactions might exceed the effect of specific volume and therefore resulted in the increase of redness with the increase of temperature and time.

4.33 Yellowness

A positive b-value represents yellowness and a negative b-value represents blueness. The average values for yellowness are presented in Table 4.5. Analysis of variance, using the GLM model, showed that the four variables: okara pellet content, moisture content, heating temperature and heating time and most of their interactions had significant effects on yellowness ($P \leq 0.05$) (Appendix B.5). The second-order polynomial regression equation that described the yellowness as a function of the four variables is as follows:

$$\boldsymbol{b} = -260.18 + 3.21 \times 10^{-1}\mathbf{X_1} + 5.08 \times 10^{-4}\mathbf{X_1} \times \mathbf{X_1} + 1.95\mathbf{X_3} - 3.40 \times 10^{-3}\mathbf{X_3} \times \mathbf{X_3} - 8.55 \times 10^{-4}\mathbf{X_1} \times \mathbf{X_3} + 1.38 \times 10^{1}\mathbf{X_4} + 1.11 \times 10^{-2}\mathbf{X_1} \times \mathbf{X_4} - 5.52 \times 10^{-2}\mathbf{X_3} \times \mathbf{X_4}$$

Here **b** is the yellowness, $\mathbf{X_1}$, okara pellet content (%) $\mathbf{X_2}$ **(**ns**)**, moisture content (%) $\mathbf{X_3}$ heating temperature (°C) and $\mathbf{X_4}$, heating time (s).

4.331 Effects of Okara and Moisture Content

The effects of okara pellet content and moisture content on yellowness are shown in Figure 4.10. Okara content and moisture content had significant effects on the yellowness of puffed soy/rice cakes according to ANOVA study ($P \leq 0.05$). The effect of okara pellet content ($P \leq 0.0001$) is more significant than moisture content ($P =$

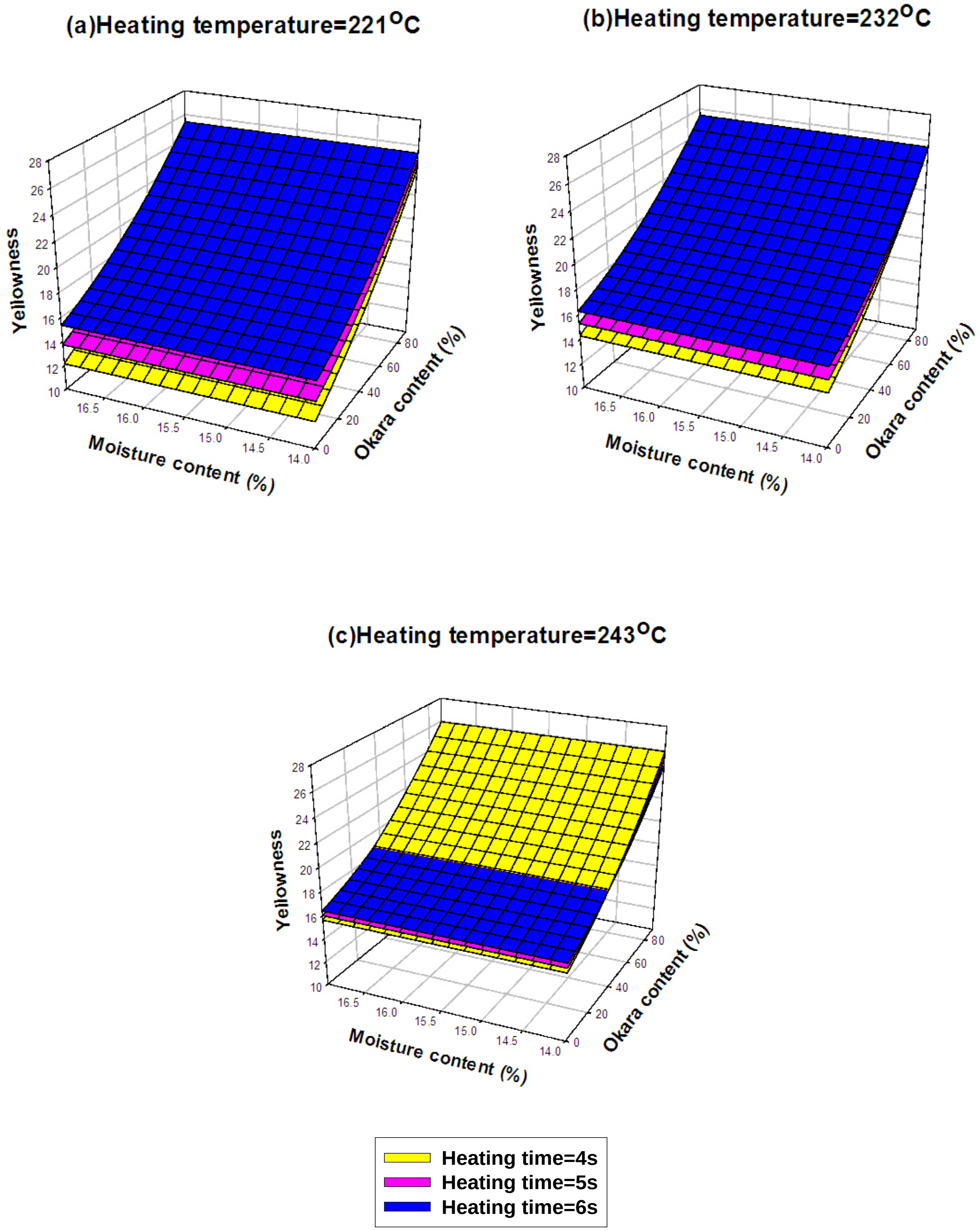
Table 4.5. Yellowness of puffed soy/rice cakes produced under different processing conditions.

Heating temperature (°C)	Heating time (s)	Okara pellet content (%) and moisture content (%)							
		0 14	0 17	40 14	40 17	70 14	70 17	90 14	90 17
221	4	11.70	11.17	17.54	19.61	20.70	19.75	24.17	23.17
	5	13.77	13.32	17.67	20.46	21.78	20.44	24.76	23.94
	6	14.82	14.89	17.27	20.30	22.99	21.10	26.23	25.35
232	4	14.16	13.76	16.98	19.65	20.14	21.38	25.95	25.20
	5	16.55	14.92	18.27	20.44	21.64	23.12	26.04	26.47
	6	16.62	16.52	17.76	19.66	20.02	22.64	26.48	28.00
243	4	14.81	15.05	18.99	20.60	21.40	24.78	25.66	26.75
	5	16.72	15.09	19.58	19.60	22.64	22.03	25.52	25.23
	6	17.17	17.43	18.00	19.22	20.55	21.37	25.72	24.28

0.0009). However, the moisture content and its interaction with other three variables in the second-order polynomial regression equation were all non-significant, which is also showed in the Figure 4.10. When the okara pellet content was raised from 0% to 90%, the average b-value increased from 14.91 to 25.50. When the moisture content was raised from 14% to 17%, the average b-value increased from 20.02 to 20.46. Figure 4.10 shows that even though the effect of moisture content on yellowness is significant according to analysis of variance, it is very small compared with the effect of the okara content.

As discussed in 4.321, the okara pellet content influenced yellowness of the puffed soy/rice cake by affecting the specific volume, or, in other words, the percentage of the surface area covered by the rice bran, the browning reactions, and the natural

Figure 4.10 Effects of okara pellet and moisture content on the HunterLab *b* value (yellowness) of the puffed soy/rice cakes at heating temperatures of 221°C, 232°C, 243°C, and at a heating time of 5 s.



brown color of the okara. Moisture content, on the other hand, had less effect on yellowness than did okara content (the same as observed on lightness and redness of the cakes). Increasing the moisture content significantly added to degree of yellowness at okara content 40 and 70%, which is supported by the results of lightness and redness. Higher moisture content led to a darker color of the cakes, especially at 40 and 70% okara pellet content, which had a more reddish color. This could be explained by the browning reaction accelerated by moisture as discussed in 4.321.

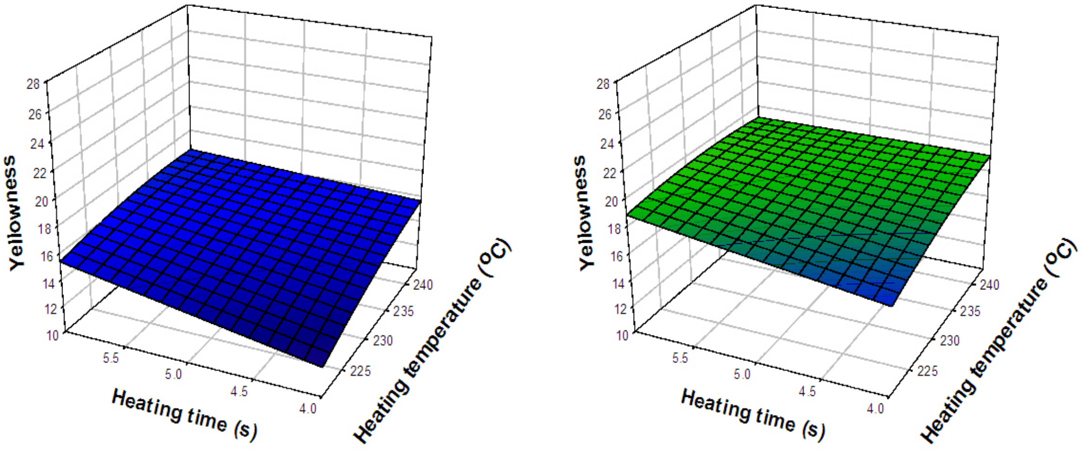
4.332 Effects of Heating Temperature and Heating Time

The effects of heating temperature and heating time on yellowness at different okara contents are shown in Figure 4.11. Because moisture and its interactions were non-significant in the second-order polynomial regression equation, plots in Figure 4.11 only demonstrated one moisture level. Heating temperature and heating time had significant effects on the yellowness of puffed soy/rice cakes ($P \leq 0.0001$). Moreover, the effect of heating temperature is more significant than heating time. Raising the heating temperature from 221^{o}C to 243^{o}C increased the b-value from 19.45 to 20.76, and increasing the heating time from 4s to 6s increased the b-value from 3.82 to 5.42.This is also in agreement with results of previous studies (Huff et al., 1992; Fan, 1996; Chen, 1997; Lee, 1999 and Zhuang, 2003).

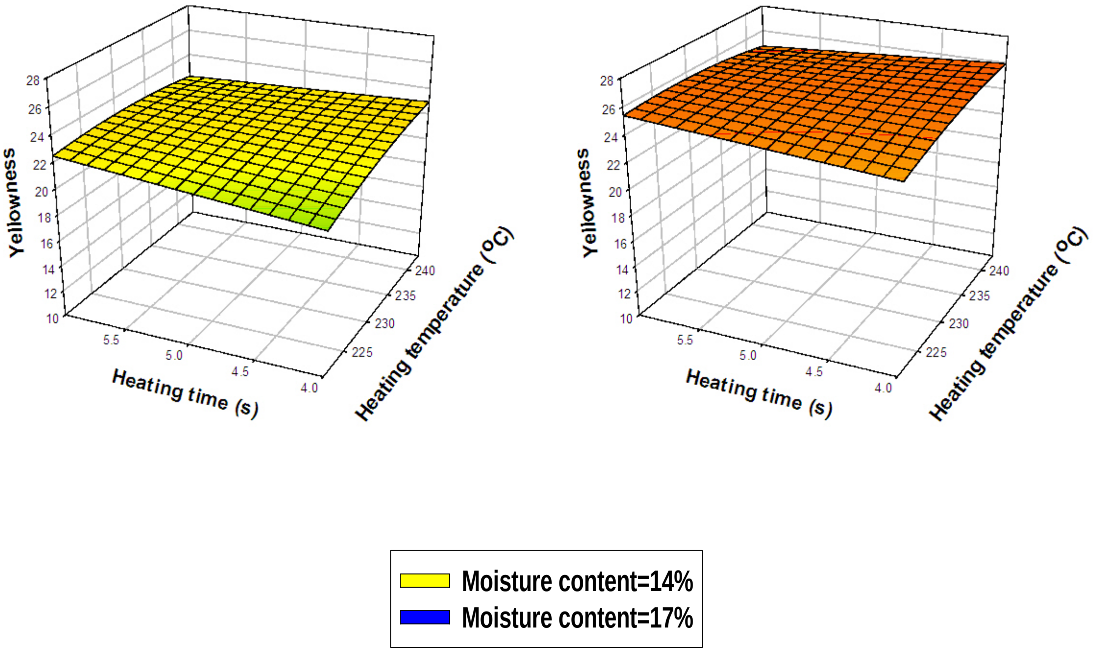
As explained in 4.322, the heating temperature and heating time influenced the yellowness of the cakes by accelerating browning reactions and increasing the specific volume of the puffed cakes. The effect of browning reactions may exceed the effect of the specific volume so that increasing heating temperature and heating time generally led to increased yellowness of the cakes.

Figure 4.11 Effects of heating temperature and heating time on HunterLab *b* value (yellowness) of the puffed soy/rice cakes at okara pellet contents of 0%, 40%, 0% and 90%, and moisture contents of 14% and 17%.

(a)Okara pellet content=0% (b)Okara pellet content=40%



(c)Okara pellet content=70% (d)Okara pellet content=90%



4.4 Integrity

The integrity of the puffed soy/rice cakes in this study was determined by percent weight loss after tumbling. Six pieces of randomly selected soy/rice cakes from each treatment combination of okara pellet content, moisture content, heating temperature and heating time were tested for hardness and the average value is shown in Table 4.6. All four factors of okara pellet content, moisture content, heating temperature and heating time and most of their interactions affected the integrity of the soy/rice cakes significantly at a 0.1% level.

The regression result of a second-order polynomial equation that describes the hardness as a function of the four variables is:

$$\boldsymbol{W} = 57.70 - 4.27 \times 10^{-1}\mathbf{X_1} + 1.09 \times 10^{-3}\mathbf{X_1} \times \mathbf{X_1} - 2.31\mathbf{X_2} + 1.84 \times 10^{-3}\mathbf{X_1} \times \mathbf{X_3} + 1.69 \times 10^{1}\mathbf{X_4} - 8.49 \times 10^{-2}\mathbf{X_3} \times \mathbf{X_4}$$

Here **W** is the cake percent weight loss after tumbling 3 min, $\mathbf{X_1}$, okara pellet content (%) $\mathbf{X_2}$, moisture content (%) $\mathbf{X_3}$, heating temperature (^{o}C) and $\mathbf{X_4}$, heating time (s).

4.41 Effects of Okara and Moisture Content

The effects of okara pellet content and moisture content on percent weight loss are shown in Figure 4.12. Okara content and moisture content had significant effects on the integrity of puffed soy/rice cakes ($P \leq 0.0001$). Decreasing the okara content and increasing the moisture content led to decreased percent weight loss or increased integrity. Similar results were reported by Chen (1997) on sorghum cakes. When the okara pellet content was raised from 0% to 90%, or the rice content was reduced from 100% to 10%,

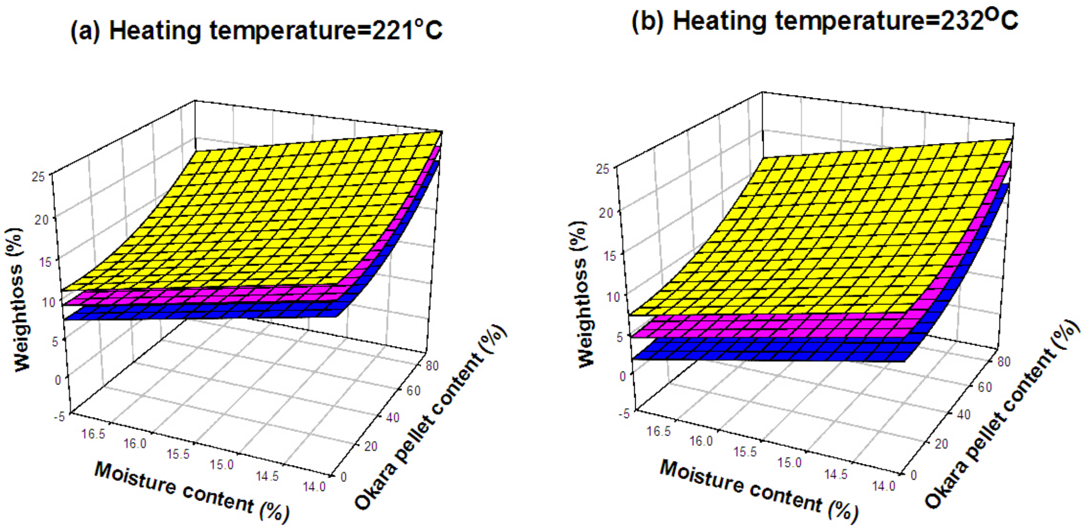
Table 4.6. Percent weight loss after tumbling for 3 min of puffed soy/rice cakes produced under different processing conditions.

Heating temperature (°C)	Heating time (s)	Okara pellet content (%) and moisture content (%)							
		0 14	0 17	40 14	40 17	70 14	70 17	90 14	90 17
221	4	31.28	13.93	23.03	3.99	15.19	34.21	21.84	25.07
	5	24.11	8.44	21.73	3.89	8.11	12.23	16.01	21.19
	6	8.10	2.59	15.75	10.34	24.38	5.53	17.04	11.61
232	4	18.94	3.08	25.53	9.15	24.27	4.72	31.64	9.72
	5	6.85	2.31	11.21	5.09	16.94	7.84	27.67	13.04
	6	3.67	2.94	18.79	4.08	9.35	7.18	26.18	6.88
243	4	4.49	2.52	11.26	6.39	10.89	8.49	20.80	7.09
	5	1.21	0.83	8.03	3.51	6.87	6.55	15.81	12.44
	6	2.99	1.24	7.59	4.16	6.46	5.26	11.91	19.36

the average percent weight loss after tumbling for 3 min increased from 7.75 to 17.52. When the moisture content was raised from 14% to 17%, the percent weight loss decreased from 15.44 to 8.52.

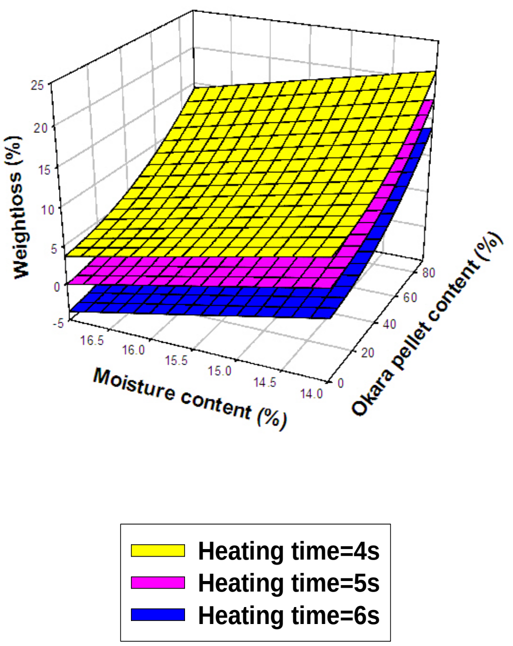
The rice content and moisture content influenced the integrity of the puffed soy/rice cakes by affecting the adhesion strength among the puffed rice kernels. Higher rice and moisture content led to increased specific volume, thus increased surface area and then raised the adhesion strength among the rice kernels. As a result, the integrity of the puffed cakes was raised.

Figure 4.12 Effects of okara pellet content and moisture content on the weight loss (%) of the puffed soy/rice cakes at heating temperatures of 221°C, 232°C, 243°C and heating times of 4 and 5 s.


(a) Heating temperature=221°C

(b) Heating temperature=232°C

(c) Heating temperature=243°C



At heating temperature 243°C, heating time 6s and low okara content, the percent weight loss was negative, which couldn't happen in real experiment. This is probably because the processing variables only had few points tested thus the regression model could not predict the trend of the weight loss precisely at extreme conditions.

4.42 Effects of Heating Temperature and Heating Time

The effects of heating temperature and heating time on percent weight loss are shown in Figure 4.13. Heating temperature and heating time had significant effects on the integrity of puffed soy/rice cakes ($P \leq 0.0001$). Moreover, the effect of heating temperature (F = 37.27) is more significant than heating time (F = 19.75). Raising heating temperature from 221°C to 243°C, the percent weight loss decreased from 15.82 to 7.76 and increasing heating time from 4s to 6s decreased the percent weight loss from 15.31 to 9.72. This is also supported by previous reports (Fan, 1996; Chen, 1997; and Zhuang, 2003).

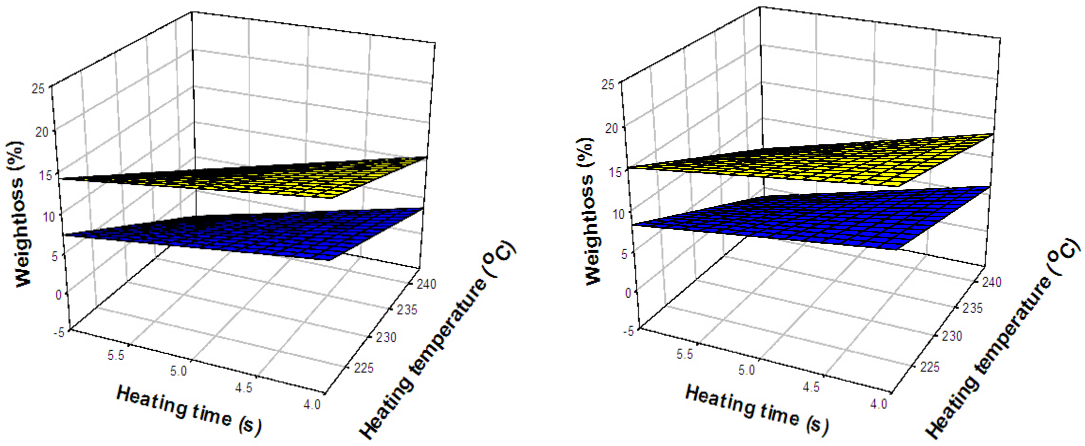
As discussed in 4.4.1, the higher heating temperature and longer heating time, the bigger the specific volume, thus, the greater the adhesion strength among the rice kernels. As a result, the integrity or percent weight loss after tumbling decreased.

Negative percent weight loss was observed at okara content 0%, 40% at high heating temperature and long heating time. As explained in section 4.4.1, this is probably due to a limited value of the variables were tested, thus the plots can not predict the percent weight loss at extreme conditions. Nevertheless, this situation may indicate that at low okara content, high heating temperature, long heating time, the soy/rice cakes have very high integrity or extremely low percent weight loss.

Figure 4.13 Effects of heating temperature and heating time on percent weight loss (%) of the puffed soy/rice cakes at okara pellet contents of 0%, 40%, 70% and 90%, and moisture contents of 14% and 17%.

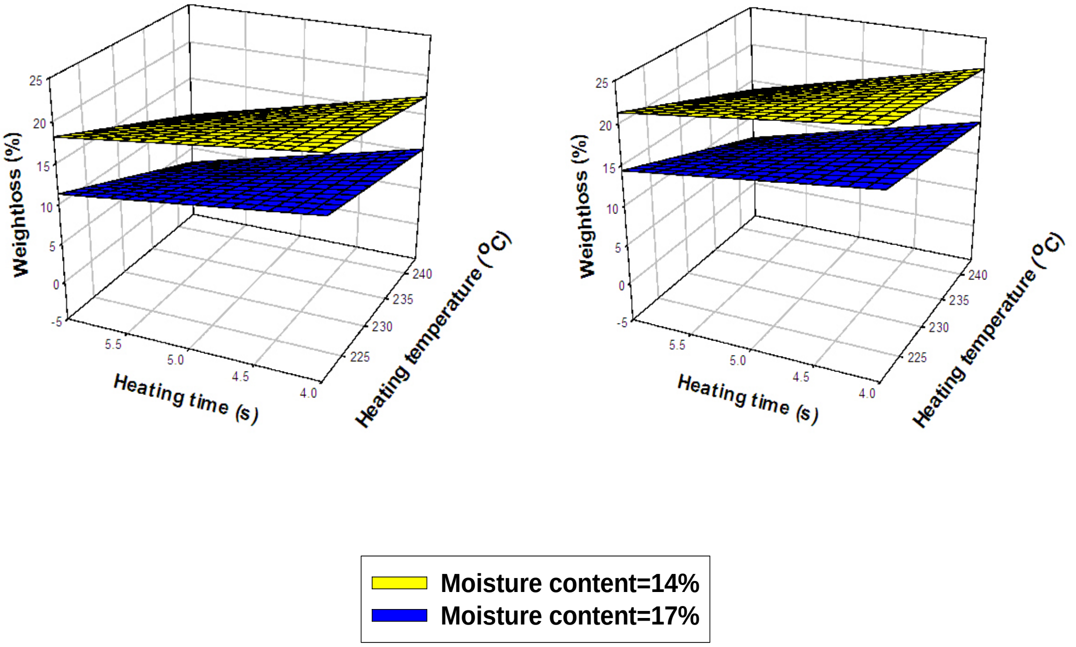
(a) Okara pellet content=0%

(b) Okara pellet content=40%



(c) Okara pellet content=70%

(d) Okara pellet content=90%



4.5 Sensory Properties of Puffed Soy/rice Cakes

One hundred and one judges were recruited to rate their preference and acceptance level of the four soy/rice cakes with different okara pellet-rice ratios and processed under different conditions (Table 3.3). According to previous tests (Table 3.3), the products had comparable physical attributes (hardness, specific volume, color and integrity). From the response of most consumer judges after the tests, the sample containing 90% okara pellets had a "burnt taste"; the samples containing 40% and 70% okara pellets were good in taste and looking and there were no beany flavor in the cakes; the regular rice cake was less attractive compared with the 40% and 70% ones.

4.51 Consumer Preference Test

The preference ranking was tested using Friedman's test (Gacula and Singh, 1984). The statistical differences in preference of the samples are summarized in Table 4.7.

The test equation based on $\chi 2$ distribution is:

$\chi 2 = 12/[N(K)(K+1)] * \sum(Tk)2 - [3(N)(K+1)]=16.03$

Here K = number of samples = 4

N = number of panelists = 110

Tk = rank totals (Table 4.19)

From a $\chi 2$ table, the critical $\chi 2$ value for $\alpha = 5\%$ and 3 degrees of freedom is 0.352 (< 16.03). Therefore, the preference ranks for the puffed soy/rice cakes differed significantly at $P \leq 0.05$.

Table 4.7. Pattern of statistical differences in preference of puffed soy/rice cakes.

Samples	0% okara pellets	40% okara pellets	70% okara pellets	90% okara pellets
Total Ranking	270^{bc}	238^{ab}	218^{a}	284^{c}

Means with the same letters are not significantly different ($P \leq 0.05$) (LSRD = 3.1937).

The "Least significant ranked difference" (LSRD) was calculated in the equation above to determine which products ranked significantly higher in preference from one another:

LSRD= t * [N*K*(K+1)]1/2 = 35.966

t (0.05, ∞)=1.96

K= 4, N = 110

This pattern can be summarized as follows: the rice cakes containing 70% okara pellets were significantly preferred than the rice cakes with 0% and 90% okara pellets; the rice cakes containing 40% okara pellets were significantly preferred than the rice cakes with 90% okara pellets; but no significant differences were found between the cakes with 70% and 40% okara pellets, cakes with 40% and 0% okara pellets and cakes with 0% and 90% okara pellets. Thus, the 70% sample received the highest preference and the 0% and 90% ones had the lowest preference. These results indicated that rice cakes made that did not contain any okara and those made with a high okara content had low preference among the judges.

4.52 Consumer Acceptance Test

The acceptance of the 4 samples of puffed soy/rice cakes were rated using the 9-point hedonic scale (“dislike extremely” 1 point and “like extremely” 9 point). Hedonic intensities of overall likeness and 4 other attributes were evaluated. ANOVA results are summarized in Table 4.8. Table 4.8 shows that for the overall likeness, the rice cakes containing 70% okara pellets obtained the highest ranking, followed by cakes with 40%, 0% and 90% okara pellets.

The rating for the 70% okara pellet treatment was significantly higher than that for the 0% and 90% treatments, while the rating for the 40% okara pellet treatment was significantly higher than that for the 90% one ($P \leq 0.05$). A similar trend was observed for the texture and mouthfeel attributes of the puffed soy/rice cakes. There was no significance difference in appearance among the cakes containing 0%, 40% and 70% okara pellets. The 90% okara pellet treatment received the lowest rating. The rating for flavor of the 70% okara pellet treatment was significantly higher than for the 90%, but no significant differences were found among the 0%, 40% and 70% okara pellet treatments.

The correlation between the attributes tested in Hedonic Scale was calculated using the SAS® program (Appendix A.6). The correlation table indicates that the appearance had less effect on the overall liking than texture, mouth feel and flavor. On the other hand, mouth feel had the greatest influence on overall liking.

Generally, the acceptance study indicated that consumers liked the cakes containing 70% okara pellets and disliked those with 90% okara pellets; the 40% okara cakes and the control (0% okara cakes) were acceptable products but were not favored by all the consumers involved in this study.

Table 4.8. Summary results for Hedonic evaluation of the 4 soy/rice cake samples using SAS program.

Sample Title/ Attribute Title/	LSD value	0% okara pellets	40% okara pellets	70% okara pellets	90% okara pellets
OVERALL LIKENESS	0.4857	5.01[a]bc[b]	5.35ab	5.76a	4.68c
APPEARANCE	0.3910	5.85a	6.03a	5.76a	4.56b
TEXTURE	0.4051	5.42b	5.84a	6.10a	5.11b
MOUTH FEEL	0.4177	5.19bc	5.51ab	5.82a	4.89c
FLAVOR	0.5080	5.03b	5.17b	5.70a	4.88b

$\text{LSD}=t^*(2\text{MSE}/N)^{1/2}=1.993^*(2\text{MSE}/4)^{1/2}$

[a] mean

[b] mean with different letter(s) across differ significantly at $P \leq 0.05$.

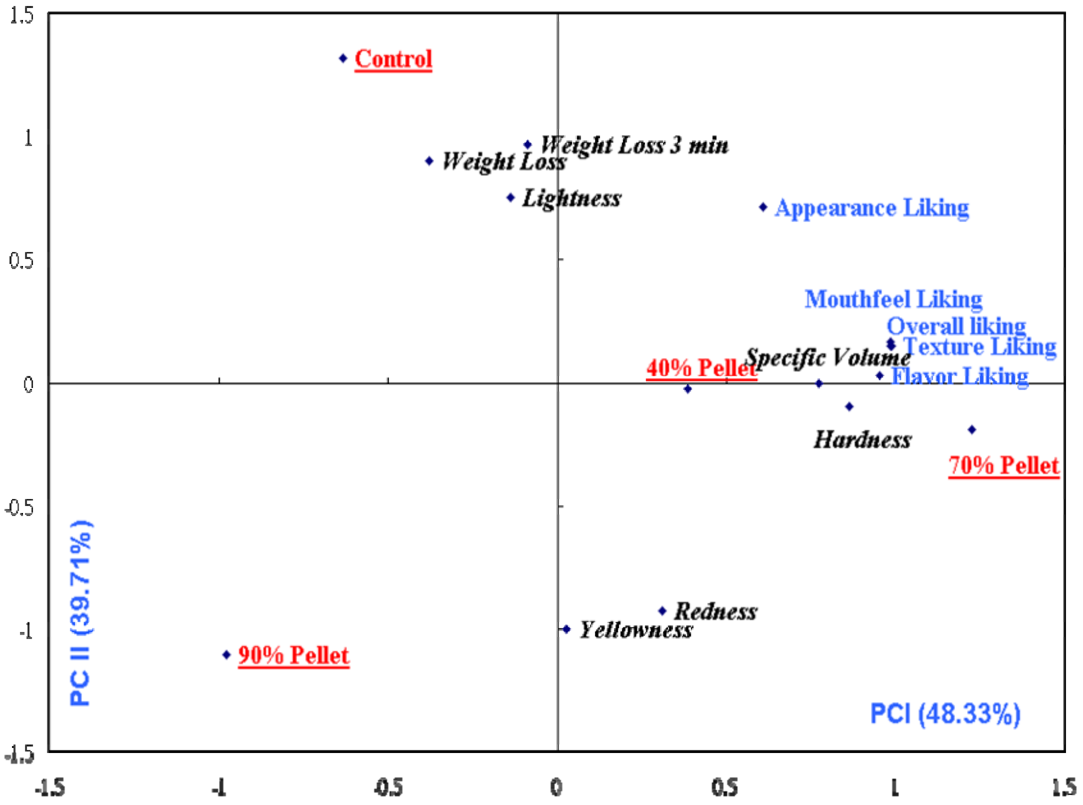
4.521 Effects of Sensory Attributes on Consumer Acceptance

4.5211 Principal Component Analysis (PCA)

Principle component analysis (PCA) using the correlation matrix was applied to describe the inter-relationships between the dependent and independent variables of the soy/rice cakes in this study. It was performed using the SAS® program to incorporate instrumental data (specific volume, hardness, color and integrity) and consumer acceptance data.

The two-dimensional correlation-PCA map for the consumer data and instrumental data of puffed soy/rice cakes is shown in Figure 4.13. In total, 88.04% of

Figure 4.14 Principle component analyses of puffed soy/rice cakes.



the variance can be explained by the first two principle components (PC1: 48.33%, PC2: 39.71%), which indicates that both of the two PCs were equally important in analyzing the correlation of these attributes. Physical attributes of the cakes are presented in Italic fonts, the consumer's liking data are in regular fonts and the soy/rice cake samples selected for the consumer hedonic test are shown in underlined fonts. "*WeightLoss*" refers to cake weight loss after tumbling for 1 min and "*Weight Loss 3 min*" refers to cake weight loss after tumbling for 3 min. The instrumental data located on the same side of a specified axis are positively correlated to one another but negatively correlated to those situated on the opposite side of the cited axis. The attributes are not correlated if their loadings to the origin formed a 90^o angle.

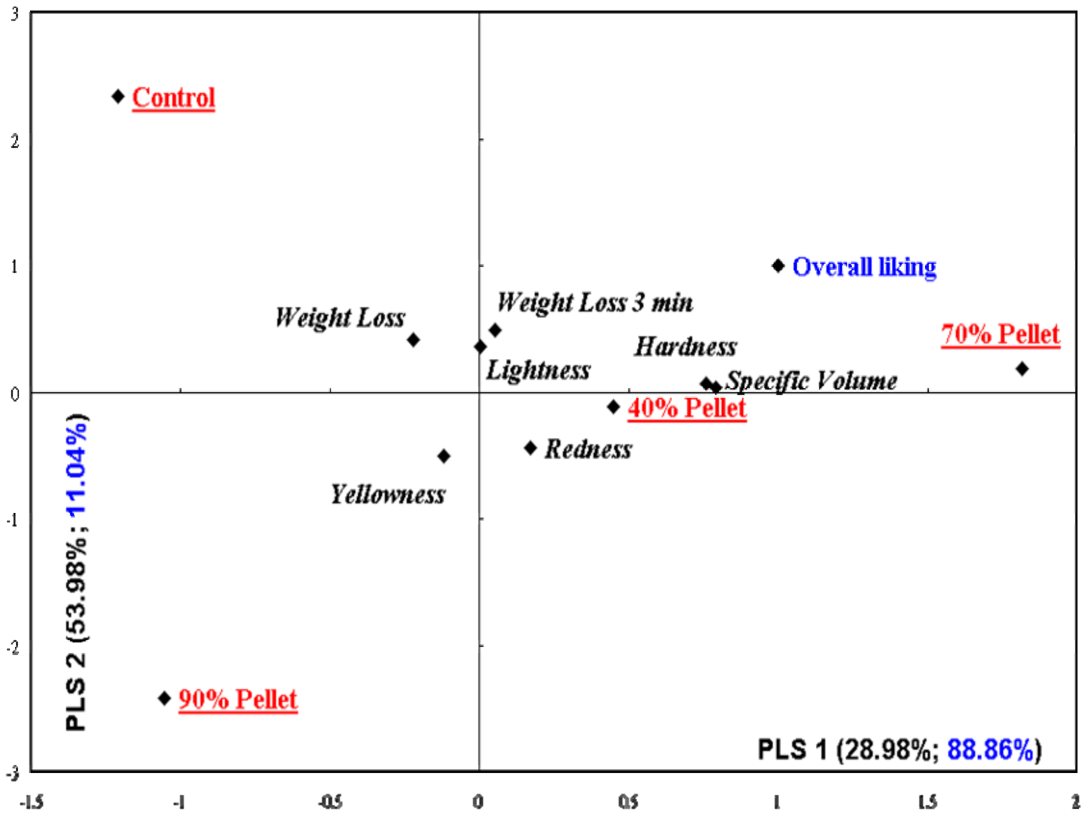
The PCA map indicates that weight loss, yellowness and redness are important factors since the lengths of the factor loadings were strong. The X-axis is dominated by the specific volume and hardness attributes. The Y-axis contrasts the attributes of weight loss and lightness with redness and yellowness. Mouthfeel liking, texture liking, flavor liking and overall liking were closely correlated with each other, which meant that the mouthfeel, texture and flavor of the cakes had a strong effect on the overall liking of the products. Appearance liking had similar lengths of loadings to both X-axis and Y-axis, which indicates that the appearance rating was equally affected by both the factors of PC1 and PC2. For PC1, overall liking, texture liking, flavor liking, mouthfeel liking and specific volume and hardness were all positively correlated. In other words, the greater the specific volume or the harder the cakes, the more the consumers liked the texture, mouthfeel and cake flavor, and the overall liking rate rose as a result. For PC2, weight loss (integrity) and lightness appeared negatively correlated with redness and yellowness of the cakes. Further, the integrity and color had a much stronger relationship with appearance liking than with the overall, mouthfeel, texture and flavor liking.

The correlation between the products and consumer liking is described below. The soy/rice cakes containing 70% okara pellets had a relatively long loading length and close distance to the overall liking and other attributes. Therefore, it had a stronger relationship with overall liking than did the other samples and it had the attributes that were favored by the consumers (specific volume, hardness, mouthfeel, texture and flavor). The 40% treatment was less associated with the instrumental and sensory attributes due to its short loading length. The control (0% okara pellet cakes) was highly associated with integrity and lightness but was less liked by the consumers. The 90% okara pellet cakes were the least liked sample and were more reddish and yellowish than the other products.

4.5212 Partial Least Squares (PLS)

To determine the drivers of liking for the selected soy/rice cake samples, Partial Least Squares (PLS) regression analysis was performed with two different data sets. Four soy/rice cake samples were evaluated and five attributes, X-matrix, were from the instrumental data. Overall liking and Y-matrix, were from the hedonic data. The analysis indicated that the first two PLS factors accounted for 81.80% of the variability in the instrumental data and 96.32% variation in the consumer acceptance data was explained from SAS program (Figure 4.15). Physical attributes of the cakes are presented in Italic fonts, the overall liking is presented in regular font and the soy/rice cakes selected for consumer hedonic tests are shown in underlined fonts. Figure 4.15 indicates that overall liking was positively correlated with specific volume, hardness, weight loss after 3 min tumbling, and lightness. Further, it was negatively associated with yellowness and, after tumbling for 1 min, appeared less related with weight loss and the redness of the cakes. In other words, the soy/rice cake samples with higher overall liking had a bigger specific volume, hardness and integrity, and a lighter color. On the other hand, the more yellowish cakes received lower ratings, which was a result of the higher okara content. The PLS results also indicated that the 70% okara treatment was the favorite sample among all the products tested, while the 40% treatment was the

Figure 4.15 Partial Least Squares of four puffed soy/rice cakes (SAS).



second liked sample. Both the 70% and 40% samples were characterized as the puffed soy/rice cakes with the preferred attributes described above. The control (0% okara pellet cakes) was less liked by consumers and the 90% sample was the least liked one, which is in accordance with the PCA result. In summary, the possible drivers of liking for the puffed soy/rice cakes appear to be the okara pellet content, hardness, specific volume, bright color and integrity of the cakes.

CHAPTER 5

CONCLUSIONS

In this research, puffed soy/rice cakes were produced from okara, the soy pulp or residue of making soymilk, and parboiled rice using a Light Energy Rice Cake Machine (Real Foods Pty Ltd. St. Peters, Australia). The processing variables were okara pellet content, moisture content, heating temperature and heating time. The effects of the four variables on specific volume, hardness, integrity, lightness, yellowness and redness of the cakes were studied.

In conclusion, (1) the specific volume of the puffed soy/rice cakes decreased significantly with the increase in okara content, and decrease in moisture content, heating temperature and heating time; (2) the hardness of the puffed soy/rice cakes increased significantly with the increase in okara content and decrease in moisture content, heating temperature and heating time; (3) the lightness decreased significantly or the redness and yellowness of the cakes increased significantly with the increase in okara content, moisture content, heating temperature and heating time; (4) the integrity of the cakes decreased significantly or the percent weight loss after tumbling increased significantly with the increase in okara content, the decrease in moisture content, heating temperature and heating time.

Higher okara content led to a smaller specific volume, higher hardness and lower integrity. This is because okara is a fibrous material which can contribute to a compact and tough texture because of its low radial expansion. In addition, increasing the okara content led to a decreased specific volume of the cakes. As a consequence, it weakened the adhesion strength among the kernels and thus decreased the integrity of the cakes.

Okara also contributed to a darker color of the soy/rice cakes because of its high protein and carbohydrate contents, which could lead to browning reactions during the puffing process.

Higher moisture content led to a bigger specific volume, lower hardness, and higher integrity. Vaporization of superheated water is the driving force of expansion. Therefore, raising the moisture content could increase the specific volume, which resulted in a thinner cell wall and therefore a lower hardness of the cakes. On the other hand, it increased the adhesion strength among the kernels and, thus, increased the integrity of the cakes. The decrease in lightness with the increase of moisture content at three heating temperatures was not obvious even though they were significant according to the P value. Therefore, the effect of moisture on the color of the puffed soy/rice cakes needs to be investigated more in the future.

Raising heating temperature and heating time contributed to a higher specific volume, hardness and integrity and a darker color. This is probably because increasing the heating temperature and time can accelerate both melting and water evaporation rates in the kernels, which resulted in a greater expansion of the cakes. For the same reason as the effect of moisture content, raising the heating temperature and time led to decreased hardness and increased integrity. In addition, higher temperatures and longer time may also accelerate browning reactions during the heating process, therefore resulting in a darker color of the cakes.

According to the consumer test, panelists did not like the rice cakes with either too low or too high okara content. Samples containing 70% okara received the highest ranking among the consumers. The PCA results indicated that overall liking, texture liking, flavor liking, mouthfeel liking and specific volume and hardness were all positively correlated, with the integrity and color having a much stronger relationship with appearance liking than with overall, mouthfeel, texture and flavor liking. The PLS results indicated that the possible drivers of liking for the puffed soy/rice cakes might be the okara pellet content, hardness, specific volume, bright color and integrity of the cakes.

The next step of research on puffed soy/rice cakes may focus on narrowing or selecting the value of okara content, moisture content, heating temperature and time, which can generate much more acceptable products. In addition, chemical analysis could be performed to study the actual nutrient value of the puffed soy/rice cakes, and a sensory descriptive test should be conducted to discriminate and describe the sensory aspects of the novel food product in detail.

APPENDIX A
ANOVA and GLM Linear Regression Program for SAS

A.1.Specific Volume

```
data one;
options pagesize=52;
title 'Okara Rice Cake---Specific Volume Results';
infile 'e:\spvokara.dat';
input trt mix ms temp time rep cake_wt jar_wt spv;
if mix=1 then okara=0;
if mix=2 then okara=90;
if mix=3 then okara =70;
if mix=4 then okara=40;
if temp=430 then temp =221;
if temp =450 then temp =232;
if temp =470 then temp =243;
proc sort; by okara ms temp time rep;
proc glm; class okara ms temp time rep;
model spv=okara|ms|temp|time rep(okara)rep(okara ms temp
time);
test h=okara|ms|temp|time e=rep(okara ms temp time);
means okara|ms|temp|time/lsd;
lsmeans okara/s p e=rep(okara);
lsmeans okara|ms|temp|time/s p e=rep(okara ms temp time);
proc glm;
model spv=okara okara*okara ms okara*ms temp temp*temp
okara*temp ms*temp  okara*time;
run;
```

A.2. Hardness

```
data one;
options pagesize=52;
title 'Okara Rice Cake---Hardness Results';
infile 'e:\hardness.prn';
input mix 4 b 5 c 6 d 7 e 8 trt 4-8 hardness;
if mix=1 then okara=0;
if mix=2 then okara=90;
if mix=3 then okara =70;
if mix=4 then okara=40;
if b=1 then ms=14;
if b=2 then ms=17;
if c=1 then temp=221;
if c=2 then temp=232;
if c=3 then temp=243;
if d=1 then time=4;
if d=2 then time=5;
if d=3 then time=6;
if e=1 then rep=1;
if e=2 then rep=2;
drop b c d e;
proc sort; by okara ms temp time rep;
proc glm; class okara ms temp time rep;
model hardness=okara|ms|temp|time rep(okara) rep(okara ms
temp time);
test h=okara e=rep(okara);
test h=okara|ms|temp|time e=rep(okara ms temp time);
means okara|ms|temp|time/lsd;
lsmeans okara/s p e=rep(okara);
lsmeans okara|ms|temp|time/s p e=rep(okara ms temp time);
proc glm;
model hardness=okara  ms ms*okara  temp  ms*temp    time
temp*time ;
run;
```

A.3. Lightness (L), redness (a) and yellowness (b)

```
data one;
title 'Okara Cake Color Results';
options pagesize=52;
infile 'e:okaracolor.dat';
input mix 4 f 5 c 6 d 7 e 8 trt 4-8 L a b;
if mix=1 then okara=0;
if mix=2 then okara=90;
if mix=3 then okara =70;
if mix=4 then okara=40;
if f=1 then ms=14;
if f=2 then ms=17;
if c=1 then temp=221;
if c=2 then temp=232;
if c=3 then temp=243;
if d=1 then time=4;
if d=2 then time=5;
if d=3 then time=6;
if e=1 then rep=1;
if e=2 then rep=2;
drop f c d e;
proc sort; by okara ms temp time rep;
proc glm; class okara ms temp time rep;
model L a b=okara|ms|temp|time rep(okara) rep(okara ms temp
time);
test h=okara e=rep(okara);
test h=okara|ms|temp|time e=rep(okara ms temp time);
means okara|ms|temp|time/lsd;
lsmeans okara/s p e=rep(okara);
proc glm;
model L = okara*okara ms*okara  temp temp*temp okara*temp
time okara*time ms*time  temp*time ;
model a = okara*okara ms okara*temp ms*time  temp*time ;
model b = okara okara*okara temp temp*temp okara*temp time
okara*time  temp*time ;
title 'glm for L a b of puffed soy/rice cakes';
run;
```

A.4. Integrity (Weight loss after tumbling 1min and 3min)

```
data one;
title 'Okara Cake Weight Loss Results';
options pagesize=52;
infile 'e:\weight.prn';
input okara 4 f 5 c 6 d 7 e 8 trt 4-8 wt1 wt2 wt5;
if okara=1 then okara=0;
if okara=2 then okara=90;
if okara=3 then okara =70;
if okara=4 then okara=40;
if f=1 then ms=14;
if f=2 then ms=17;
if c=1 then temp=221;
if c=2 then temp=232;
if c=3 then temp=243;
if d=1 then time=4;
if d=2 then time=5;
if d=3 then time=6;
if e=1 then rep=1;
if e=2 then rep=2;
drop f c d e;
wtloss1min=((wt1-wt2)/wt1)*100;
wtloss3min=((wt1-wt5)/wt1)*100;
proc glm; class okara ms temp time rep;
model wtloss1min wtloss3min =okara|ms|temp|time rep(okara)
rep(okara ms temp time);
test h=okara e=rep(okara);
test h=okara|ms|temp|time e=rep(okara ms temp time);
means okara|ms|temp|time/lsd;
lsmeans okara/s p e=rep(okara);
lsmeans okara|ms|temp|time/s p e=rep(okara ms temp time);
model wtloss3min =okara okara*okara ms okara*temp time
temp*time;
run;
```

A.5. Principle Component Analysis (PCA)

```
title1 'Cor-PCA for soycake';
filename in 'E:\data2all.csv';
data soycake;
infile in dlm=',' dsd truncover LRECL=800;
input Name$ hard spv yellow light red weight weight3
overall appear texture mouth flavor;
proc factor data=soycake scree score corr outstat=stuff
rotate=none method=prin mineigen=0.01;
 var hard spv yellow light red weight weight3 overall
appear texture mouth flavor;
proc score data =soycake scores=stuff out=scores;
 var hard spv yellow light red weight weight3 overall
appear texture mouth flavor;
proc print data=scores;
run;
```

A.6. Partial Least Square (PLS) 1

```
title1 'PLS for soycake';
filename in 'e:\data1overall.csv';
data soycake;
infile in dlm=',' dsd truncover LRECL=800;
input product$ hardness spv yellow light red weight weight3
overall;
proc pls data=soycake method=pls cv=random
cvtest(stat=PRESS)censcale varss details;
model overall=hardness spv yellow light red weight
weight3/solution;
output out=outpls xscore=xscr;
proc print data=outpls;
run;
proc pls data=soycake method=pls varss details;
model overall=hardness spv yellow light red weight
weight3/solution;
output out=outpls xscore=xscr;
proc print data=outpls;
run;
```

A.7. Partial Least Square (PLS) 2

```
title1 'PLS for soycake';
filename in 'f:\data2all.csv';
data soycake;
infile in dlm=',' dsd truncover LRECL=800;
input product$ hardness spv yellow light red weight weight3
overall appear texture mouthfe flavor;
proc pls data=soycake method=pls cv=random
cvtest(stat=PRESS)censcale varss details;
model overall appear texture mouthfe flavor=hardness spv
yellow light red weight weight3/solution;
output out=outpls xscore=xscr;
proc print data=outpls;
run;
proc pls data=soycake method=pls varss details;
model overall appear texture mouthfe flavor=hardness spv
yellow light red weight weight3/solution;
output out=outpls xscore=xscr;
proc print data=outpls;
run;
```

APPENDIX B
GLM Analysis of Variance Output

B.1. Specific Volume

The GLM Procedure

Dependent Variable: hardness

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	143	6269.255546	43.840948	80.01	<.0001
Error	576	315.624960	0.547960		
Corrected Total	719	6584.880506			

R-Square	Coeff Var	Root MSE	spv Mean
0.952068	12.75103	0.740243	5.805361

Source	DF	Type III SS	Mean Square	F Value	Pr > F
okara	3	4056.600738	1352.200246	2467.70	<.0001
ms	1	108.593534	108.593534	198.18	<.0001
okara*ms	3	41.124392	13.708131	25.02	<.0001
temp	2	1294.273960	647.136980	1180.99	<.0001
okara*temp	6	333.694618	55.615770	101.50	<.0001
ms*temp	2	46.067950	23.033975	42.04	<.0001
okara*ms*temp	6	65.650014	10.941669	19.97	<.0001
time	2	89.623779	44.811889	81.78	<.0001
okara*time	6	46.514979	7.752497	14.15	<.0001
ms*time	2	3.966642	1.983321	3.62	0.0274
okara*ms*time	6	12.754682	2.125780	3.88	0.0008
temp*time	4	0.955832	0.238958	0.44	0.7826
okara*temp*time	12	15.722650	1.310221	2.39	0.0051
ms*temp*time	4	3.589974	0.897493	1.64	0.1632
okara*ms*temp*time	12	4.159882	0.346657	0.63	0.8150
rep(okara)	4	21.392270	5.348067	9.76	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
rep(oka*ms*tem*time)	68	124.569650	1.831907	3.34	<.0001

B.2. Hardness

The GLM Procedure

Dependent Variable: hardness

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	143	75062860.1	524915.1	4.63	<.0001
Error	1296	146961514.5	113396.2		
Corrected Total	1439	222024374.6			

R-Square	Coeff Var	Root MSE	hardness Mean
0.338084	22.76664	336.7436	1479.110

Source	DF	Type III SS	Mean Square	F Value	Pr > F
okara	3	5774748.11	1924916.04	16.98	<.0001
ms	1	612170.69	612170.69	5.40	0.0203
okara*ms	3	8111219.47	2703739.82	23.84	<.0001
temp	2	3464124.35	1732062.17	15.27	<.0001
okara*temp	6	14223731.75	2370621.96	20.91	<.0001
ms*temp	2	3409821.47	1704910.74	15.03	<.0001
okara*ms*temp	6	3304958.41	550826.40	4.86	<.0001
time	2	920906.92	460453.46	4.06	0.0175
okara*time	6	1661488.26	276914.71	2.44	0.0237
ms*time	2	286762.87	143381.44	1.26	0.2827

Source	DF	Type III SS	Mean Square	F Value	Pr > F
okara*ms*time	6	576585.01	96097.50	0.85	0.5333
temp*time	4	2958257.83	739564.46	6.52	<.0001
okara*temp*time	12	3753338.48	312778.21	2.76	0.0010
ms*temp*time	4	1269613.54	317403.38	2.80	0.0249
okara*ms*temp*time	12	7116655.43	593054.62	5.23	<.0001
rep(okara)	4	724024.68	181006.17	1.60	0.1729
rep(oka*ms*tem*time)	68	16894452.84	248447.84	2.19	<.0001

B.3. Lightness

The GLM Procedure

Dependent Variable: L

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	143	60367.28041	422.14881	49.22	<.0001
Error	1584	13584.43703	8.57603		
Corrected Total	1727	73951.71744			

R-Square	Coeff Var	Root MSE	L Mean
0.816307	4.033941	2.928487	72.59617

Source	DF	Type III SS	Mean Square	F Value	Pr > F
okara	3	46534.21190	15511.40397	1808.69	<.0001
ms	1	822.25926	822.25926	95.88	<.0001
okara*ms	3	615.32285	205.10762	23.92	<.0001
temp	2	2721.29728	1360.64864	158.66	<.0001
okara*temp	6	434.14628	72.35771	8.44	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
ms*temp	2	220.01811	110.00906	12.83	<.0001
okara*ms*temp	6	1050.31142	175.05190	20.41	<.0001
time	2	1927.69092	963.84546	112.39	<.0001
okara*time	6	236.88322	39.48054	4.60	0.0001
ms*time	2	243.25039	121.62520	14.18	<.0001
okara*ms*time	6	254.67370	42.44562	4.95	<.0001
temp*time	4	907.35729	226.83932	26.45	<.0001
okara*temp*time	12	294.63891	24.55324	2.86	0.0007
ms*temp*time	4	25.45987	6.36497	0.74	0.5632
okara*ms*temp*time	12	448.46691	37.37224	4.36	<.0001
rep(okara)	4	365.89895	91.47474	10.67	<.0001
rep(oka*ms*tem*time)	68	3265.39314	48.02049	5.60	<.0001

B.4. Redness

The GLM Procedure

Dependent Variable: a

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	143	9945.52393	69.54912	64.12	<.0001
Error	1584	1718.24537	1.08475		
Corrected Total	1727	11663.76930			

R-Square	Coeff Var	Root MSE	a Mean
0.852685	22.42024	1.041514	4.645417

Source	DF	Type III SS	Mean Square	F Value	Pr > F

Source	DF	Type III SS	Mean Square	F Value	Pr > F
okara	3	7222.607387	2407.535796	2219.44	<.0001
ms	1	4.817556	4.817556	4.44	0.0352
okara*ms	3	88.899960	29.633320	27.32	<.0001
temp	2	1342.226145	671.113072	618.68	<.0001
okara*temp	6	50.856193	8.476032	7.81	<.0001
ms*temp	2	12.698556	6.349278	5.85	0.0029
okara*ms*temp	6	46.482914	7.747152	7.14	<.0001
time	2	743.866865	371.933432	342.87	<.0001
okara*time	6	58.546648	9.757775	9.00	<.0001
ms*time	2	14.403401	7.201700	6.64	0.0013
okara*ms*time	6	23.777591	3.962932	3.65	0.0013
temp*time	4	24.172653	6.043163	5.57	0.0002
okara*temp*time	12	19.804764	1.650397	1.52	0.1095
ms*temp*time	4	12.901699	3.225425	2.97	0.0184
okara*ms*temp*time	12	19.623769	1.635314	1.51	0.1143
rep(okara)	4	6.695950	1.673987	1.54	0.1872
rep(oka*ms*tem*time)	68	253.141884	3.722675	3.43	<.0001

B.5. Yellowness

The GLM Procedure

Dependent Variable: b

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	143	29385.23103	205.49113	27.11	<.0001
Error	1584	12007.43104	7.58045		
Corrected Total	1727	41392.66207			

R-Square	Coeff Var	Root MSE	b Mean
0.709914	13.60169	2.753262	20.24205

Source	DF	Type III SS	Mean Square	F Value	Pr > F
okara	3	25650.02902	8550.00967	1127.90	<.0001
ms	1	84.59715	84.59715	11.16	0.0009
okara*ms	3	382.04073	127.34691	16.80	<.0001
temp	2	555.35245	277.67623	36.63	<.0001
okara*temp	6	374.88708	62.48118	8.24	<.0001
ms*temp	2	61.70623	30.85311	4.07	0.0173
okara*ms*temp	6	233.53484	38.92247	5.13	<.0001
time	2	254.49701	127.24850	16.79	<.0001
okara*time	6	433.76174	72.29362	9.54	<.0001
ms*time	2	41.28835	20.64417	2.72	0.0660
okara*ms*time	6	31.20842	5.20140	0.69	0.6609
temp*time	4	333.90073	83.47518	11.01	<.0001
okara*temp*time	12	114.47984	9.53999	1.26	0.2372
ms*temp*time	4	101.00960	25.25240	3.33	0.0100
okara*ms*temp*time	12	85.53609	7.12801	0.94	0.5052
rep(okara)	4	13.22967	3.30742	0.44	0.7825
rep(oka*ms*tem*time)	68	634.17210	9.32606	1.23	0.1013

B.6. Integrity

The GLM Procedure

Dependent Variable: wtloss3min

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	143	36609.03198	256.00722	4.05	<.0001
Error	288	18199.22077	63.19174		
Corrected Total	431	54808.25276			

R-Square	Coeff Var	Root MSE	wtloss3min Mean
0.667947	66.33698	7.949323	11.98325

Source	DF	Type III SS	Mean Square	F Value	Pr > F
okara	3	5405.118417	1801.706139	28.51	<.0001
ms	1	5169.426759	5169.426759	81.81	<.0001
okara*ms	3	638.724285	212.908095	3.37	0.0190
temp	2	4709.754447	2354.877223	37.27	<.0001
okara*temp	6	1067.328435	177.888072	2.82	0.0112
ms*temp	2	1673.679859	836.839929	13.24	<.0001
okara*ms*temp	6	2009.088563	334.848094	5.30	<.0001
time	2	2496.448019	1248.224010	19.75	<.0001
okara*time	6	567.387492	94.564582	1.50	0.1791
ms*time	2	291.520604	145.760302	2.31	0.1014
okara*ms*time	6	659.472206	109.912034	1.74	0.1117
temp*time	4	695.908478	173.977120	2.75	0.0284
okara*temp*time	12	1416.167796	118.013983	1.87	0.0381
ms*temp*time	4	820.711425	205.177856	3.25	0.0126
okara*ms*temp*time	12	2972.238479	247.686540	3.92	<.0001
rep(okara)	4	189.556390	47.389098	0.75	0.5587
rep(oka*ms*tem*time)	68	5826.500331	85.683828	1.36	0.0462

B.7. Correlation of the Variables tested in Hedonic Scale (SAS).

	OVERALL	APPEARANCE	TEXTURE	MOUTH FEEL	FLAVOR
OVERALL	1				
APPEARANCE	0.696475399	1			
TEXTURE	0.991956476	0.738230744	1		
MOUTH FEEL	0.998739085	0.722804224	0.996762049	1	
FLAVOR	0.956979578	0.497224618	0.915466966	0.941269975	1

B.8. ANOVA result of Hedonic Test (Compusense 5® version 4.6)

Question Title/ Attribute Title/ Standard Dev.	p value	Control Mean	40%okara pellets Mean	70% pellets Mean	90% pellets Mean
OVERALL LIKENESS					
OVERALL LIKENESS	0.0001	5.01 bc	5.35 ab	5.76 a	4.68 c
(SD)		(1.76)	(1.77)	(1.84)	(1.98)
APPEARANCE					
APPEARANCE	0.0000	5.85 a	6.03 a	5.76 a	4.56 b
(SD)		(1.55)	(1.30)	(1.52)	(1.73)
TEXTURE					
TEXTURE	0.0000	5.42 bc	5.84 ab	6.10 a	5.11 c
(SD)		(1.75)	(1.34)	(1.34)	(1.73)
MOUTHFEEL					
MOUTHFEEL	0.0001	5.19 bc	5.51 ab	5.82 a	4.89 c
(SD)		(1.69)	(1.60)	(1.58)	(1.78)
FLAVOR					
FLAVOR	0.0100	5.03 ab	5.17 ab	5.70 a	4.88 b
(SD)		(1.87)	(1.83)	(2.06)	(2.07)

APPENDIX C
Sensory Materials

C.1. Consent Form-Soy/Rice Cakes

You are invited to participate in a study investigating the sensory attributes of soy/rice cakes manufactured using traditional parboiled rice, rice flour, soy pulp (okara) and caramel/cheese flavor. Okara is the insoluble residue left from soymilk or tofu manufacture. It is very nutritious as a rich source of dietary fiber, vitamin B group and high quality protein, the amount of which is approximately the same as that found in milk. You will be asked to taste 3 different samples and 1 control (no okara added).

This study is strictly for research purposes only. Any information obtained in connection with you will remain strictly confidential and will only be disclosed with permission from you. You will be assigned a code number and the study coordinator will be conducting the study in a randomized fashion using only code numbers, not subjects= names. Data and results generated in this study will be published in scientific reports and journal articles but all subjects will retain their anonymity.

You must be 18 years or older to participate in this study. You cannot be included in the study if you are pregnant or if you have any kind of allergy to soy products. **If any research-related injury occurs during the course of the study, treatment will be available but payment is the responsibility of the subject and/or third party payer.**

Your decision whether or not to participate will not prejudice your future relations with the University of Missouri. If you decide to participate, you are free to withdraw and discontinue participation at any given time without prejudice.

If you have any questions at any time, please do not hesitate to contact the Principle Investigator of this study, Dr. Azlin Mustapha, at 882-2649, E-mail: MustaphaA@missouri.edu, 221 Eckles Hall. This project has received approval by the Campus Institutional Review Board (IRB) for Human Subjects. If you have further questions, you may contact the Campus IRB Compliance Office at 483 McReynolds Hall, tel: 882-9585.

Please indicate your agreement to participate in this study by signing this consent form on the following page. ***Your signature indicates that you have thoroughly read and understood the information provided and that you have agreed to participate.*** **You may withdraw at any time without prejudice after signing this form if you choose to do so. You will be given a copy of this form to keep for your records.**
Thank you for your participation.

Name: ______________________________

Signature:___________________________ **Date:** ________________

Address:____

____

Phone: (Work) ________________________________

(Home) ________________________________

E-mail:____

Principal Investigator:___________Azlin Mustapha_____**Signature:** ______________

Study Coordinator: ______________________________**Signature:** ______________

C.2. Score Sheet

WELCOME TO
SOY RICE CAKE TEST!!

To start, click on the 'Continue' button below:

Panelist Code: ______________________

Panelist Name: ____

Review Instructions

Review Instructions

This is a consumer test of soy/rice cakes. It is composed of two parts: the RANKING test and LIKENESS test.

You will be tasting FOUR samples of soy/rice cakes

Before you start, please make sure you have a cup of water, a spit cup and some tissues. If you need any of them at any time, please turn on the switch flip only once.

Directions:

1. Please masticate a piece of baby carrot and rinse your mouth with water before you start.
2. Please taste the three coded samples clockwise in the sequence of 1, 2, 3, 4 as marked on the table.
3. Open the plastic bag containing the soy/rice cakes, masticate one of the cakes and spit it into the spit cup.
4. Please masticate a piece of carrot and rinse your mouth with water before tasting the next sample.
5. After you have finished tasting the four samples, please do the 'RANKING' test.
6. After you have finished conducting the 'RANKING' test, please taste the FIRST sample again carefully, and evaluate the 'LIKENESS' part. Please masticate a piece of carrot and rinse your mouth each time before tasting a different sample.

Question # 1.

Please rank the rice cakes in order of **Preference**. Rank the sample from the one you like **MOST** to the one you like **LEAST**.

Rank	**Sample #**
________	________
________	________
________	________
________	________

Question # 2 - Sample ______

Please rate the overall LIKENESS of the soy/rice cakes by placing a mark on the scale below that describes your opinion of the sample.

OVERALL LIKENESS

dislike extremely	dislike very much	dislike moderately	dislike slightly	neither like nor dislike	like slightly	like moderately	like very much	like extremely
1	2	3	4	5	6	7	8	9

Question # 3 - Sample ______

Please rate how much you like or dislike the APPEARANCE of the soy/rice cakes by placing a mark on the scale below that describes your opinion of the sample.

APPEARANCE

dislike extremely	dislike very much	dislike moderately	dislike slightly	neither like nor dislike	like slightly	like moderately	like very much	like extremely
1	2	3	4	5	6	7	8	9

Question # 4 - Sample ______

Please rate how much you like or dislike the TEXTURE of the soy/rice cakes by placing a mark on the scale below that describes your opinion of the sample.

TEXTURE

dislike extremely	dislike very much	dislike moderately	dislike slightly	neither like nor dislike	like slightly	like moderately	like very much	like extremely
1	2	3	4	5	6	7	8	9

Question # 5 - Sample ______

Please rate how much you like or dislike the MOUTHFEEL of the soy/rice cakes by placing a mark on the scale below that describes your opinion of the sample.

MOUTHFEEL

dislike extremely	dislike very much	dislike moderately	dislike slightly	neither like nor dislike	like slightly	like moderately	like very much	like extremely
1	2	3	4	5	6	7	8	9

Question # 6 - Sample ______

Please rate how much you like or dislike the FLAVOR of the soy/rice cakes by placing a mark on the scale below that describes your opinion of the sample.

FLAVOR

dislike extremely	dislike very much	dislike moderately	dislike slightly	neither like nor dislike	like slightly	like moderately	like very much	like extremely
1	2	3	4	5	6	7	8	9

REFERENCES

Adolph, W. H. and Kao, H. C. 1932. Hemoglobin building properties of soy bean products. Chin. J. Physiol. 6:257-264.

Adoph, W. H. and Kiang, P. C. 1920. The nutritional value of soybean products. Chin. Med. J. 34:268-275.

Anderson, J. W., Deakins, D. A., Floore, T. L., Smith, B. M., and Whitis, S. E. 1990. Dietary fiber and coronary heart disease. CRC Crit. Rev. Food Sci. Nutr. 29(2):95-147.

Anon. 1985. Energy and protein requirement. Report of a Joint FAO/WHO/UNU Expert Consultation. World Health Organization Technical Report Series 724. Geneva, Switzerland.

Anon. 1989. Two studies show rice bran reduces cholesterol levels. Food Chem. News 31(37):40.

Anon. 1996. 28th Annual State of the Snack Food Industries Report. Snack Food 85(6):SI55-57.

Anon. 1997. Tempeh. http://www.soyfoods.com/soyfoodsdescriptions/Tempeh.html#anchor1434636. Indiana Soybean Board. Available June 1st.

Anon. 1998. Specialty snacks. Snack Food & Wholesale Bakery 87(6):SI-68.

Anon. 2005. Snack Food. http://en.wikipedia.org/wiki/Snack_food. Available June 1st.

Baianu, I. C., Pessen, H. and Kumosinski, T. F. 1992. Physical Chemistry of Food Processes. Vol. 1. New York: Van Nostrand Reinhold. 360 p.

Bils, R. F. and Howell, R. W. 1963. Biochemical and cytological changes in developing soybean cotyledons. Crop Sci. 3:304-308.

Booth, R. G. 1990. Snack Food. New York: Van Nostrand Reinhold. 401 p.

Bourne, M. C., Clemente, M. G. and Banzon, J. 1976. Survey of the suitability of thirty cultivars of soybeans for soymilk manufacture. J. Food Sci. 41:1204-1208.

Chandrasekhar, P. R. and Chattopadhyay, P. K. 1990. Studies on microstructural changes of parboiled and puffed rice. J. Food Process. Preserv. 14(1):27-37.

Chen, M. C. 1997. Puffing of sorghum cakes using a rice cake machine. M.S. Thesis. Columbia, MO: University of Missouri. 104 p.

Chen, W. J. L. and Anderson, J. W. 1981. Soluble and insoluble plant fiber in selected cereals and vegetables. Am. J. Clin. Nutr. 34(6):1077-1082.

Chinnaswamy, R. and Bhattacharya, K. R. 1984. Relationship between amylase content and expansion characteristics of parboiled rice. J. Cereal Sci. (2)4: 273-279.

Davídek, J., Velísek, J. and Pokorný, J. 1990. Chemical changes during food processing. Amsterdam; New York: Elsevier. 448 p.

Dolecek T. A. 1992. Epidemiologic evidence or relationships between dietary polyunsaturated fatty acids and mortality in the Multiple Risk Factor Intervention Trial. PSEBM 200:177-182.

Fairweather-Tait, S. J.; Symss, L. L.; Smith, A. C. and others. 1987. The effect of extrusion cooking on iron absorption from maize and potato. J. Sci. Food Agric. 39(4):341-348.

Fan S. 1997. Puffing of wheat cakes using a rice cake machine. M.S. Thesis. Columbia, MO: University of Missouri. 122 p.

Frame N. D. 1994. The technology of extrusion cooking. London: Chapman & Hall. 253 p.

Friedenwald, J. and Ruhrah, J. 1910. The use of the soy bean as a food in diabetes. Am. J. Med. Sci. 140:793-83.

Gacula, M. C., Jr. and Singh, J. 1984. Statistical methods in food and consumer research. Orlando: Academic Press, Inc. 505 p.

Guermani, L., Villaume, C., Bau, H. W., Chandrasiri, V., Nicolas, J. P. and Mejean, L. 1993. Composition and nutritional value of okara fermented by *Rhizopus oligosporus*. Sciences des Aliments 12:441-451.

Harper, J. M. 1981. Extrusion of foods. Vol. 2. Boca Raton: CRC. Press, Inc. 174 p.

Harper, J. M. 1989. Food extruders and their applications. In: Mercier, C., Linko, P., and Harper J. M. Extrusion cooking. St. Paul: American Association of Cereal chemists. 1-15 p.

Hasegawa, Y. 1998. Manufacture of high-strength ceramics by utilizing pozzolanic reaction and recycling of fly ashes and okara. Japanese Patent (Jpn Koukai Tokkyo Kouhou) no. JP 10025156 a2.

Hayashi, H., Takiuchi, K., Murao, S. and Arai, M. 1989. Structure and insecticidal activity of new indole alkaloids, okaramines A and B, from *Penicillium simplicissimum* AK-40. Agric. Biol. Chem. 53:461-470.

Hsieh, F., Mulvaney, S. J., Huff, H. E., Lue, S. and Brent, J., Jr. Effect of dietary fiber and screw speed on some extrusion processing and product variables. 1989. Food Sci & Technol-Leb 22(4):204-207.

Hirotsuka, M., Harada, T., Ohtsubo, N., Kawade, H., Hayakawa, Y. and Taniguchi, H., inventors. Fuji Oil Company, Ltd, assignee. 1987 Oct. 27. Method for drying water retentive substance. U.S. Patent US 04702927.

Huff H. E., Hsieh F. and Peng I. C. 1992. Rice cake production using long-grain and medium-grain brown rice. J. Food Sci. 57(5):1164-1167.

Israel D. H. and Gorlin R. 1992. Fish oils in the prevention of atherosclerosis. J. Am. Coll. Cardiol. 19:174-185.

Jolliffe, I. T. 1986. Principal Component Analysis. New York: Springer-Verlag. 271 p.

Kahlon, T. S., Saunders, R. M., Chow, F. I., Chiu, M. M. and Betschart. 1990. Influence of rice bran, oat bran and wheat bran on cholesterol and triglycerides in hamsters. Cereal Chem. 67:439-443.

Kato, T., Shiga, I. and Terasawa, K. 1986. Preservation of okara (soybean residue from soy mash) by lactic acid fermentation. J. Jpn. Soc. Food Sci. Tech. [Nippon Shokuhin Kogyo Gakkaishi] 33: 837-841.

Katz, E. E. and Labuza, T. P. 1981. Effect of water activity on the sensory crispness and mechanical deformation of snack food products. J. Food Sci. 46:403-409.

Kay, R. M. 1982. Dietary Fibre. J. Lipid Res. 23:221-228.

Khare, S. K., Jha, K. and Gandhi, A. P. 1995a. Citric acid production from okara (soy-residue) by solid state fermentation. Biores. Technol. 54:323-325.

Khare, S. K., Jha, K. and Gandhi, A. P. 1993. Physico-chemical and functional properties of okara protein isolate. J. Dairying, Foods Home Sci. 12(3):132-136.

Khare, S. K., Jha, K. and Sinha L. K. 1995b. Preparation and nutritional evaluation of okara fortified biscuits. J. Dairying, Foods Home Sci. 14(2):91-94.

Kitamura, Y., Kanno, Y., Tagawa, A. and Hayashi, H. 1996. Studies on the process for utilizing okara. II. Product inhibition in enzymatic saccharification of okara. J. Jap. Soc. Food. Sci. Technol. 43:404-406.

Kloppel, K. 1998. Puffing of white and yellow dent corn using a rice cake machine. M.S. Thesis. Columbia, MO: University of Missouri. 171 p.

Lawton, B. T., Henderson, G. A. and Derlatka, E. J. 1972. Effects of extruder variables on the gelatinization of corn starch. Can. J. Chem. Engin. 50(4):168-172.

Lee, Y. H. 1999. Puffing of pearled barley cakes using a rice cake machine. M.S. Thesis. Columbia, MO: University of Missouri. 161 p.

Liu, K. S. 1997. Soybeans: chemistry, technology, and utilization: Chapman & Hall. New York. 532 p.

Liu, K. S. 2000. Expanding soybean food utilization. Food Technol. 54(7):46-58.

Lu, H. C. 1990. Chinese foods for longevity: the art of long life. New York: Sterling Publishing Co., Inc. 192 p.

Lue, S. 1990. Extrusion cooking of corn meal and dietary fiber. Ph.D. Dissertation, Columbia, MO: University of Missouri . 176 p.

Ma, C. Y., Liu, W. S., Kwok, K. C. and Kwok, F. 1996. Isolation and characterization of proteins from soymilk residue (okara). Food Res. Int. 2:799-805.

Maeda, H., Furuta, H., Yoshida, R., Takahashi, T., Sato, Y., Hisakawa, M. and Teranishi, S., Inventors. Fuji Oil Co., Ltd., assignee. 1998 Jan. 20. Preparation of water-soluble polysaccharide from plants and a demethoxylation process. U.S. Patent 5710270.

Martens, H. and Martens, M. 2001. Multivariate analysis of quality: an introduction, Chichester; New York: John Wiley & Sons, Ltd. 445 p.

Mastuo, M. 1991. Effects "okara tempe" on fat digestion and cholic acid metabolism in vitro. J. Jpn. Soc. Nutr. Food Sci. [Nihon Eiyo Shokuryo Gakkai shi] 44:399-402.

Mastuo, M. 1996. Acceleration of sterol excretion, little meteorism, and less inhibition of iron absorption by okara koji, a new foodstuff, in rats. Biosci. Biotechnol. Biochem. 60:571-574.

Mastuo, M. and Hitomi, E. 1992. Okara koji suppression of plasma cholesterol and hepatic lipid accumulation in rats. J. Agric. Chem. Soc. Japan [Nippon Nogeikagaku Kaishi] 66:899-904.

Miller, R.C. 1985. Low moisture extrusion: Effects of cooking moisture on product characteristics. J. Food Sci. 50:246-253.

Messina M., Messina, V. and Kenneth, D. R. S. 1994. The simple soybean and your health. Garden City Park. New York: Avery Publishing Group. 260 p.

Muramatsu, N., Karasawa, H., Kaneko, S., Ohhinata, H. and Ohike, T. 1995a. Effects of addition of water-absorbing synthetic polymers to okara on dehydration and cohesion. Food Technol. 23:28-31.

Muramatsu, N., Karasawa, H., Kaneko, S., Ohhinata, H. and Ohike, T. 1995b. Effects of use of water-absorbing synthetic polymers sheets on dehydration from okara. Food Technol. 23:32-36.

Muramatsu, N., Karasawa, H., Kaneko, S., Ohhinata, H. and Ohike, T. 1995c. Drying test of water-absorbing synthetic polymers and okara. Food Technol. 23:37-43.

Myers, D. J. 1993. Industrial applications for soy protein and potential for increased utilization. Cereal Food World 38:355-360.

Noguchi, A, inventor. Director of National Food Research Institute, assignee. 1987 Feb. 10. Method for the preparation of textured soybean draff. U.S. patent 04642241.

Ohno, A., Ano, T. and Shoda, M. 1996. Use of soybean curd residue, okara, for the solid-state substrate in the production of a lipopeptide antibiotic, iturin A, by *Bacillus subtilis* NB22. Process Biochem. 31(8):801-806.

Orts, W. J., Glenn, G. M. and Noves, G. A. R. 2000. Wheat starch effects on the textural characteristics of puffed brown rice cakes. Cereal Chem. 77(1):18-23.

Park, K. H. 1976. Elucidation of the extrusion puffing process. Dissertation Abstracts International B, 37(1):148.

Payne, F. A., Taraba, J. L. and Saputra, D. 1989. A review of puffing processes for expansion of biological products. J. Food Engin. 10(3):183-197.

Pomper, K. W. and Breen, P. J. 1997. Expansion and osmotic adjustment of strawberry fruit during water stress. J. Am. Soc. Hort. Sci. 122(2):183-189.

Raper, N. R, Cronin, F. J. and Exler, J. 1992. Omega-3 fatty acid content of the US food supply. J. Am. Coll. Nutr. 11:304-308.

Sacchetti, G., Pinnavaia, G. G., Guidolin, E. and Rosa, M. D. 2004. Effects of extrusion temperature and feed composition on the functional, physical and sensory properties of chestnut and rice flour-based snack-like products. Food Res. Int. 37(5):527-534.

Saio, K. 1979. Tofu-Relationships between texture and fine structure. Cereal Food World 24(8):342-345, 350-354.

Saio, K., Koyama, E., Yamazaki, S. and Watanabe, T. 1969a. Protein-calcium-phytic acid relationships in soybean. Part III. Effect of phytic acid on coagulative reaction in tofu-making. Agric. Biol. Chem. 33:36-42.

Saio, K., Kamiya, M. and Watanabe, T. 1969b. Food processing characteristics of soybean 11S and 7S proteins. Part I. Effect of difference of protein components among soybean varieties on formation of tofu-gel. Agric. Biol. Chem. 33:1301-1308.

Saunders, R. M. 1990. The properties of rice bran as a foodstuff. Cereal Food World 35(7):632-635.

Schuler, E. W. 1986. Twin-screw extrusion cooking system for food processing. Cereal Food World 31(6):413-416.

Shurtleff, W. and Aoyagi, A. 1983. The Book of Tofu. Berkley: Ten Speed Press. 335 p.

Shurtleff, W. and Aoyagi, A. 1979. The Book of Tempeh, New York: Harper & Row, Publishers, Inc. 248 p.

Shurtleff, W. and Aoyagi, A. 2004. History of Soybean Fiber Products: Okara (Soy Pulp) and Soy Bran (Ground Hulls) http://www.thesoydailyclub.com/SFC/NFsoyfoods37. asp. Available June 1st.

Simoons F. J. Food in China: A cultural and historical inquiry. 1991. Boca Raton: CRC press Inc. p 559.

Smith, A. K. and Circle, S. J. 2001. Chemical composition of the seed. In: Soybeans: Chemistry and Technology. Vol. 1, Proteins, ed. A. K. Smith and S. J. Circle. Westport: The AVI Publishing Company, Inc. 61-92 p.

Sumida, M., Yuhki, T., Chen, R., Mori, H., Imamura, T. and Matsubara, F. 1995. Aseptic rearing of original silkworm strains on an artificial diet throughout the entire larval instars. J. Seric. Sci. Jpn. 64:35-38.

Synder H. E. and Kwon T. W. 1987. Soybean utilization. New York: Van Nostrand Reinhold Co. 131 p.

Tabachnick, B. G. and Fidell, L. S. 1983. Using Multivariate Statistics. 4th ed. New York: Harper & Row. 50 9p.

The American Dietetic Association (ADA) comments on proposed rule for meat alternatives used in child nutrition programs. 1986. J. Am. Dent. Assoc. 86:530-531.

Tso, E. 1929. A vegetable milk substitute for North China. Am. J. Physiol. 90:542.

Tso, E. and Chu, F. T. 1931. Nitrogen metabolism in infants on graded intake of soybean “milk” proteins. Chin. J. Physiol. 5:287-294.

Van der Riet, W. B., Wight, A. W., Cilliers, J. J. L. and Datel, J. M. 1989. Food chemical investigation of tofu and its byproduct okara. Food Chem. 34:193-202.

Wallingford, J. C. and Yetley, E. A. 1991. Development of the health claims regulations: the case of omega-3 fatty acids and heart disease. Nutr. Rev. 49:323-331.

Wang, H. L. and Cavins, J. F. 1989. Yield and amino acid composition of fractions obtained during tofu production. Cereal Chem. 66(5):359-361.

Weinheimer, A. and Golbitz, P. 2002. Soyfoods, the U.S. Market 2002. San Francisco & Bar Harbor: SPINS, Inc. & Soyatech, Inc.

Yokota, T., Ohami, H., Ohishi, H., Hattori, T. and Watanabe, K. 1996. Repression of acute gastric mucosal lesions by antioxidant containing fraction from fermented products of okara (bean-curd residue). J. Nutr. Sci. Vitaminol. 42:167-172.

Zhuang, S. M. 2003. Puffing of potato rice blends using a rice cake machine. M.S. Thesis. Columbia, MO: University of Missouri. 117 p.