KULLAYA LIMROONGREUNGRAT
Development of pasta product using sweetpotato flour
(Under the direction of YAO-WEN HUANG)

Development of new pasta products using sweetpotato flour was investigated. Sweetpotato flour (SPF), prepared from an orange-flesh domestic cultivar (Beauregard), was used as a major ingredient in pasta formulation. Addition of up to 30% tapioca flour in pasta formulation containing 2.0% xanthan gum, 0.1% ascorbic acid and 0.5% monoglyceride, reduced cooking loss and increased firmness of pasta that was fortified with 10% wheat gluten (WG) or 10% whey protein concentrate (WPC).

In order to improve the pasting characteristics of flour, sweetpotato flour was modified with sodium hypochlorite (NaOCl) solution under an alkaline condition. Modified sweetpotato flour (MSPF), replaced partially with native SPF (0, 15, 30%) and defatted soy flour (DSF) (0, 15, 30%), was used to make pasta using both extrusion and steaming method. Substitution with native SPF and DSF in pasta formulation increased cooking loss and decreased firmness of cooked pasta ($p<0.05$). Up to 30% of DSF addition, without SPF replacement, could yield a pasta with the same quality as pasta made from 100% MSPF.

The effect of chemical modification on pasting characteristics of sweetpotato flour was studied. SPF and commercial sweetpotato starch (CSPS) suspensions were adjusted to pH 10.5 by using 2M NaOH solution with or without NaOCl addition. The paste viscosity determined by using Brabender viscoamylograph of alkaline treated sweetpotato flour (ASPF) and modified sweetpotato flour (MSPF) significantly increased as compared to that of SPF. However, the viscosity of alkaline treated commercial sweetpotato starch (ACMSPS) just slightly increased. In order to keep sweetpotato nutrients, pasta products were made from MSPF and ASPF. No significant difference among cooking characteristics and color of pasta made from MSPF and ASPF was observed.

Soy protein concentrate (SPC) and DSF at 0, 15, 30, and 45% were used to fortify pasta formulation made with ASPF. A 15% DSF and SPC substitution produced the pasta with the same quality as pasta made with 100% ASPF. The protein and β-carotene contents of products, fortified with 15% DSF or 15% SPC, ranged from 8.9 to 10.4% (dry weight) and 7.8 to 7.9 mg/100g, respectively.

INDEX WORDS: Sweetpotato flour, Modified sweetpotato flour, Pasta, Defatted soy flour, Soy protein concentrate, Wheat gluten, Whey protein concentrate, β-carotene, Cooking quality, Color, Texture

DEVELOPMENT OF PASTA PRODUCT USING SWEETPOTATO FLOUR

by

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A Dissertation Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

DOCTOR OF PHILOSOPHY

ATHENS, GEORGIA

2001

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DEDICATION

This work is dedicated to my beloved parents, Kovit and Rossukon Limroongreungrat, my brother, Weerawat, and my sister, Nattaya, for their love, support and encouragement.

ACKNOWLEDGMENTS

I would like to express my gratitude to my major professor, Dr. Yao-wen Huang, for his encouragement, academic guidance and support. I would like to acknowledge Dr. Ronald R. Eitenmiller, Dr. Robert L. Shewfelt, Dr. Robert D. Phillips, and Dr. William L. Kerr, my advisory committee members, for their encouragement, advice and support.

I would like to thank Dr. Philip E. Koehler, Dr. Romeo T. Toledo, Dr. Stanley J. Kays, Ms. Kay H. McWatters and Dr. Klanarong Sriroth, Head of Cassava and Starch Technology Research Unit, National Center for Genetic Engineering and Biotechnology, Thailand, for their advice and letting me use their lab facilities.

I would like to extend my deep appreciation to Dr. Lin Ye, Dr. Yvonne Mensa-Wilmot, Ms. Ruth Ann Rose-Morrow, Ms. Anne Morrison, and Ms. Wonda Rogers for their assistance and technical advice in the lab.

I also want to give special thanks to friends in the Department of Food Science and Technology including Abel Ragotonirainy, Sunisa Siripongvutikorn, Panida Banjongsinsiri, Walairut Chantarapanont, Firibu Saliaa, Soo-Voon Len and members of Thai Student Association for their friendship and support. I also want to thank to the office staff and Mr. Elijah McStotts for their assistance.

My special thanks go to the Royal Thai Government for financial support for my whole program of study and Burapha University for letting me take a leave to study.

Finally, and most importantly, I thank my father, Kovit, my mother, Rossukon, my brother, Weerawat, and my sister, Nattaya for their ever lasting love, support and encouragement.

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CHAPTER 1

INTRODUCTION

Sweetpotato is an inexpensive tropical root crop that provides many benefits to humans. Because of high nutrition, easy growing, and being a short period crop, the sweetpotato has been playing an important role in solving food shortage and malnutrition problems in many developing countries. In the past, people did not realize its importance. The sweetpotato seemed to be a food of the poor in many countries. This belief makes the development of sweetpotato products very slow. However, in some countries such as Papua New Guinea and the Philippines, the sweetpotato is consumed as a staple food (Villareal et al.; 1982; Yang, 1982). The sweetpotato is also used as a co-staple food. It can be mixed with rice or other grains (Woolfe, 1992). In fact, the sweetpotato is a very useful plant because it can be used as food, feed, and industrial products such as starch and alcohol. All parts of the sweetpotato plants can be utilized including fresh roots, leaves and tips. In addition, the waste or by-products from sweetpotato starch and alcohol industries can also be exploited to produce single cell protein and baker's yeast (Wirano, 1982). Recently, the sweetpotato is classified as a health food because of high dietary fiber, vitamin and mineral contents (Kays, 1992; Woolfe, 1992). Its leaves are consumed as green or vegetables whereas its roots may be cooked by baking, boiling and frying or used to prepare flour, flake, and starch. Although sweetpotato has a lot of advantages, the consumption has been decreased due to a few products available in the market.

Pasta consumption has been popular in many countries. Even in the U.S., pasta consumption is rising steadily, and development of new pasta products has been investigated (Giese, 1992). Pasta contains a large amount of carbohydrates, moderate amount of proteins, some essential vitamins, and minerals. It is also low in fat and saturated fat. Many product varieties are provided in the market including macaroni, spaghetti, ravioli, noodles and the like. Typical pasta is made from durum wheat semolina and other wheat flour. However, other ingredients such as eggs, vegetables, and soy protein can be added to enhance the nutrition value of products (Miskelly, 1993).

The development of pasta products by utilizing non-wheat raw materials, such as rice, starch or potato flour, maize, and legumes, has received a considerable amount of attention. However, these raw materials called “non-conventional materials” are considered to be difficult for pasta production because of low quantity and quality of protein. Three approaches have been raised to solve this problem including using new technologies such as extrusion cooking and high temperature drying, addition of selected additives, and fortifying the raw material with proteins able to form complexes similar to gluten (Pagani, 1986; Giese, 1992).

Among non-conventional raw materials, sweetpotato has a great potential to produce pasta because of being a good source of carbohydrates, β-carotene, dietary fiber, and other vitamins and minerals. In addition, sweetpotato has a potential to increase the production yield. It can be harvested within 3-4 months and can be grown all year round in the tropical areas. Since pasta is a staple food and consumed worldwide, it could be a good vehicle to deliver the nutrients from sweetpotato to consumers. From previous research, sweetpotato flour was used as a minor ingredient or as a wheat substitute. Thus, this research attempted to use sweetpotato flour to make pasta without wheat. Since sweetpotato flour contained starch as a major component, it could be used to produce pasta products, which their structure based on starch matrix. Therefore, the objectives of this study were:

1. To develop new pasta product by using sweetpotato flour as a main ingredient.
2. To develop the method to produce pasta by using chemically modified sweetpotato flour.
3. To enhance the protein content of sweetpotato pasta by fortification with different protein sources.

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CHAPTER 2

LITERATURE REVIEW

Origin and history of sweetpotato

According to the archeological, linguistic, and historical evidence, it is believed that the sweetpotato originated in tropical America (Yen, 1982; Woolfe, 1992). It was cultivated by the Mayans in Central America and by the Peruvians in the Andes. In prehistoric times, the sweetpotato distribution dated to approximately 400 AD by the 'kumara' line, from South America to Polynesia (this area comprises Columbia, Equador and northern Peru), before European exploration. In historic times, the lines of sweetpotato transmission can be divided into two lines: A) The 'batatus" line, which began in the time of Columbus' discovery in 1492. The plant was disseminated to Europe, and continuing after 1500 AD, transferred to Africa, Asia, and the East Indies by Portuguese explorers. B) The 'kamote' line, which showed that the sweetpotato was transferred from Mexico to the Philippines by the Manila galleons in the sixteenth century. Since that time, the sweetpotato has been available worldwide in many countries (Edmond and Ammerman, 1971; Yen, 1982; Woolfe, 1992).

General description of the plant

Sweetpotato (*Ipomoea batatus*) is a dicotyledonous plant that is in the family *Convolvulaceae*. This family comprises approximately 50 genera and more than 1,400 species (Anon., 1997). However, only the sweetpotato has an important role. Although the sweetpotato is a perennial plant, it is usually grown as an annual and propagated from vine cuttings in the tropics or from rooted sprouts ‘slips’ in the temperate regions. The morphology of sweetpotato plant can be described as the follows (Edmond and Ammerman, 1971; O’Hair, 1990; Woolfe, 1992).

Stem

Sweetpotato stems vary in length from 2 to 20 ft, depending on the cultivars (bush varieties or varieties with ‘running’ vines).

Leaf

The leaf system composes of the blades (leaves) and the petiole. The blades vary in size and shape, depending on the age of the plant and different environment. The petioles, slender stems that supports the blade of a foliage leaf, vary in length (3 to 10 in.), thickness, and color, depending on the variety.

Root

The root system has two important functions:

a) Absorbing: the roots absorb water and essential nutrients from the soil,

b) Fleshy or storage: the roots are variable in size, shape, composition, color of skin, and color of flesh.

The color of skin varies from white to deep red, whereas, the color of flesh ranges from white to light yellow and orange.

Flower

The flower of the sweetpotato has trumpet-shaped and characteristic of the morning glory family. A mature flower opens before dawn, and stays open only a few hours. It closes and wilts before noon on the same day. Therefore, chances of failure by pollination are high, and seed production is difficult.

Fruit

The fruit is a capsule 5-8 mm in diameter. It consists only 1 or 2 black 3-mm long seeds in its chamber. It also has a very hard seed testa or outer coat.

The propagation of the sweetpotato is classified into two types. First, asexually propagation is used by growers or farmers to produce fleshy roots. The sweetpotato is propagated from young plants, which are called sprouts, slips or draws, and vine cuttings. Second, sexually propagation is used by breeders to develop new varieties. The seed is used for propagation. Normally, the growth cycle of the sweetpotato is about 105 to 210 days, but it can be harvested within 100-150 days (Edmond and Ammerman, 1971; Woolfe, 1992; Ramirez, 1991).

Two basic types of the sweetpotato in the U.S. are classified as moist flesh that soft when cooked and dry flesh that firm when cooked. Moist flesh types including Jewel, Centennial, Southern Delite, Georgia Jet and Garnet are grown in the Southern states whereas dry flesh types are grown in the Northeast and Middle Atlantic states (Lucier, 1993). The sweetpotato markets have focused on luxury types, which have copper skin, deep orange flesh, sweetness and moist texture. The most popular cultivars in the U.S. are Centennial, Jewel, Georgia Jet (O'Hair, 1990) and Beauregard (Cannon, 1997).

Beauregard sweetpotato was released in 1987 by Dr. Larry Ralston, Louisiana State University (LSU) Agricultural Center (Benedict, 1997). Recently, Beauregard has become popular because of good taste, good appearance, more disease resistance, and high production yield (Cannon, 1997). Beauregard was classified as moist flesh type (Walter et al., 2000).

Distribution

Sweetpotato is the seventh in rank of total world production of food crops (Yen, 1982). According to FAO (1999), the greatest sweetpotato production area is Asia that consists of 89.9% of world production, followed by Africa (7.5%). The countries that have a great production of sweetpotato are China (83.6%), Indonesia (1.6%), Vietnam (1.3%), India (1.0%) and Japan (0.9%) in Asia, and Uganda (2.1%), Nigeria (1.3%) and Rwanda (0.83%) in Africa.

In the U.S., commercial sweetpotato production is popular in the south. The top five producing states are North Carolina, Louisiana, California, Alabama, and Texas (Lucier, 1993). However, the U.S. only produces 0.5 percent of world production (FAO, 1999). This may due to a few products available on the markets. Generally, sweetpotatoes are consumed as fresh, canned, patty and baby foods (Collins, 1993).

Composition and Nutrition

The composition and nutrition of the sweetpotato varies as varieties. In different production areas, the composition and nutritive values are different. However, starch is the major component of every cultivar. The sweetpotato is also considered as a good source of vitamin A, especially in the orange-flesh variety, which has a considerable amount of β-carotene. The composition of the sweetpotato root is shown in Table 2.1.

The composition of sweetpotato can be described as the followings.

Dry matter content

The sweetpotato has high moisture content (66.10-71.10%) like other root crops (Anon., 1989). The dry matter content in each variety is variable depending on many

Table 2.1. The composition of sweet potato root and leaves

Component	Roots[1,2] (% dry matter)	Vines[1] (% dry matter)
Starch	30-80	6.6-15
Total sugar	5-38	8.8-13
Total protein (N x 6.25)	1.2-10.0	18.2-20.9
Lipid	1.0-2.5	—[4]
Ash	0.6-4.5	12.5-17.7
Total fiber	9.07-12.16[3]	14.9-26.2
Vitamins and other components	<1	—

[1]Dominguez, 1992

[2]Woolfe, 1992

[3]Mullin et al., 1994

[4]— : not available

factors such as cultivation, location, climate, and soil types. Dry matter content varies from about 10% to 50%. Generally, the average dry matter content is about 30% (Anon., 1989; Woolfe, 1992).

Carbohydrates

Carbohydrates are the major component in the sweetpotato roots, about 80-90% of the dry matter. It can be classified as monosaccharides, oligosaccharides and polysaccharides. The first two groups in sweetpotato roots are sugars such as sucrose, glucose, fructose, maltose and raffinose. The polysaccharides compose of many diverse constituents, for example: starch (70%), cellulose (2%), hemicellulose (3-4%) and pectic substances (2.5%) (Palmer, 1982; Kays, 1992). In recent years, people are interested in dietary fiber, which is shown to decrease blood cholesterol, colon cancer, diabetes, and heart diseases. Sweetpotato has fiber content ranging from a low level to such a high levels of 9-12%, depending on the size, and presence of woody roots (Kays, 1992; Mullin et al., 1994). The tops of the sweetpotato, which compose of stems, petioles and leaves, contain the amount of dietary fiber more than the roots do.

Protein

The average protein content is about 5% in dry weight or 1.5% in fresh weight, including all nitrogenous compounds. Crude protein is composed of true (coagulable) protein about 75% and non-protein nitrogen (NPN) about 25%, containing amino acids (88%) and amides (Kays, 1992; Woolfe, 1992). The major amino acids found in the sweetpotato are asparagine (61%), aspartic acid (11%), glutamic acid (4%), serine (4%)

and threonine (3%) (Purcell and Walter, 1980). According to the Table 1, the vines contain more protein content (on a dry weight basis) than the roots do.

Lipid

The lipid content in the sweetpotato is low and variable among the varieties. It ranges from 0.1% to 0.8% (wet weight) varying with cultivars. Lipid in the sweetpotato can be divided into 3 groups: neutral lipids (42.1%), glycolipids containing sugar (30.8%) and phospholipids containing phosphorus (27.1%). The sweetpotato composes of many types of fatty acid. The highest contents of fatty acids are palmitic acid (16:0) and linoleic acid (18:2), which comprising 29.3% and 44.7% of total lipids, respectively (Walter et al., 1971; Woolfe, 1992).

Vitamins

The sweetpotato is a very good sources of vitamins especially β-carotene, which can be converted to vitamin A in the human body. Cream to pale yellow sweetpotatoes contained 0.184 to 0.368 mg/100 g (wet weight). The cultivars with deep orange flesh are the rich source of β-carotene, which ranged from 3.36 to 19.60 mg/100 g (wet weight) (Woolfe, 1992). It also contains a substantial amount of vitamin C (9.5-25 mg/100g). Other vitamins include thiamin (0.04-012 mg/100g wet weight), riboflavin (0.02-0.06mg/100g), niacin (0.26-0.84 mg/100g), and α-tocopherol or vitamin E (0-10 mg/100g) (Collins and Walter, 1982; Kays, 1992; Woolfe, 1992).

Organic acid

Organic acids affect flavor, taste, stability, and keeping quality of the sweetpotato. They are variable with cultivars. Major organic acids are malic, quinic, succinic and citric acid. Although the sweetpotato contains of a small amount of oxalic acid, it can cause health problem if consumed without cooking. Because oxalic acid can bind with calcium salt to form a crystal of calcium oxalate, it can cause diseases such as hypocalcaemia and crystals in the kidney (Kays, 1992; Woolfe, 1992).

Minerals

The sweetpotato composes of many kinds of mineral and trace elements; however, mineral contents are variable with varieties, production areas, seasons, soil types, and fertility. Minerals with high concentration in the sweetpotato root include potassium (250-450 mg/100g wb), phosphorus (29-57 mg/100g wb), calcium (17-45 mg/100g wb), and magnesium (18-36 mg/100g wb), while minerals contained in sweetpotato tips are potassium (3018 mg/100g wb), calcium (836-1351mg/100g wb), magnesium (432 mg/100g wb), and phosphorus (264 mg/100g wb) (Villareal et al., 1982: Kays, 1992; Woolfe, 1992).

Pigments

Pigments in the sweetpotato can be classified in 3 groups: carotenoids, flavonoids, and chlorophylls. Carotenoids present include β-carotene (vitamin A precursor), and its derivative, xanthophyll. Flavonoids comprise many classes such as anthocyanidins, flavones, catechins and flavonals. The important pigments in the sweetpotato are carotenes (containing in cream to orange flesh), and anthocyanins (containing in red to purple flesh) (Kays, 1992; Woolfe, 1992).

β-carotene

Carotenoid pigments especially β-carotene are responsible for the cream, yellow, and orange color of sweetpotato flesh. The yellow-orange flesh sweetpotatoes are the best source of β-carotene, which is provitamin A. Simonne et al. (1993) categorized sweetpotato lines into four groups based on β-carotene content as follows: (1) lines with very high β-carotene (>130 μg/g dw), (2) lines with moderate β-carotene (40-129 μg/g dw), (3) lines with low β-carotene (1-39 μg/g dw), and (4) lines containing nondetectable levels of β-carotene (<1 μg/g dw).

Beta-carotene has the highest provitamin activity. It is composed of two beta-ionone rings, one at either end of a long polyene chain (Fig. 2.1). Theoretically, one molecule of β-carotene can be cleaved into two molecules of retinol (vitamin A). Thus, 2 μg of β-carotene is equivalent to 1μg of vitamin A activity. However, due to absorption differences, 6 μg of β-carotene is equivalent to 1μg of retinol. Therefore, 1 retinol equivalent (RE) equals 1μg of retinol, 6 μg of β-carotene, and 12 μg of other provitamin A carotenoids (National Research Council, 1989). Recently, new data have shown that the vitamin A activity of provitamin A carotenoids is only half of that previous estimated. Thus, 1 retinol activity equivalent (RAE), a new term, equals 1μg of retinol, 12 μg of β-carotene, and 24 μg of other provitamin A carotenoids (Yates and Trumbo, 2001).

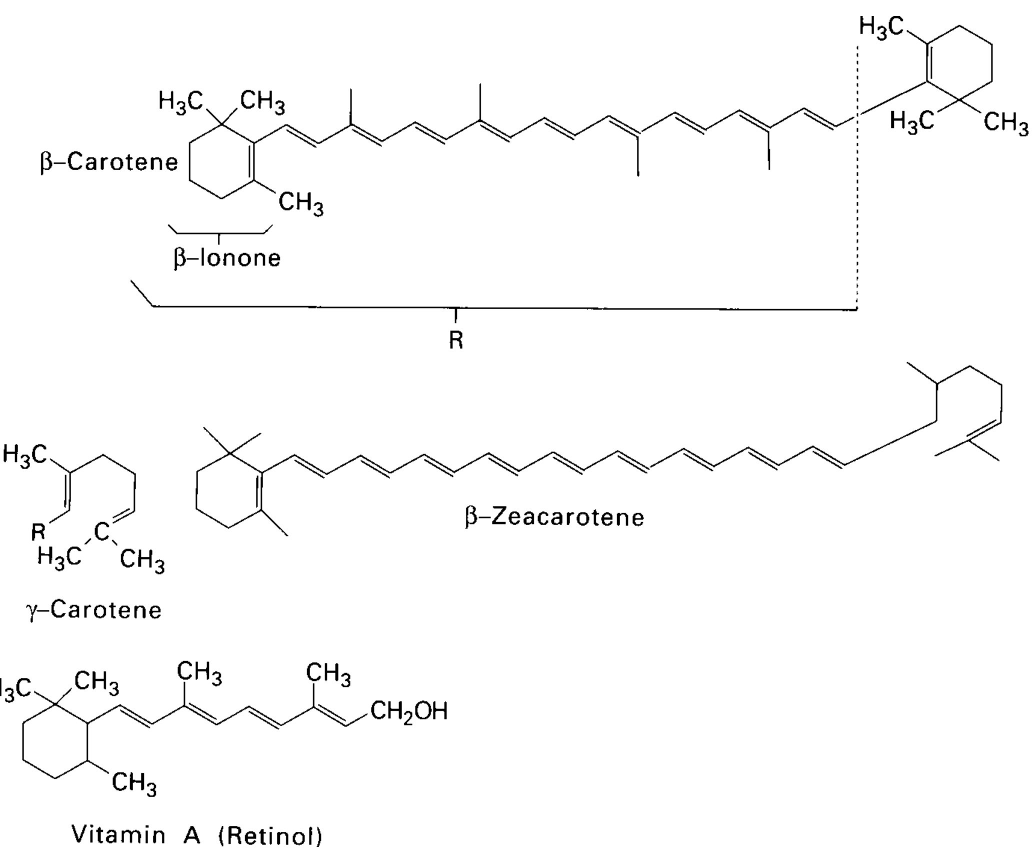

Fig.2.1 Chemical structures of some carotenoids in sweetpotato and vitamin A (retinol)

Sweetpotato Flour

Sweetpotato flour has been used in bakery production in developing countries for many years. Generally, sweetpotato flour is used as a substitute for wheat flour in many products such as bakery products, noodles, and soy sauce (Data et al., 1986; Woolfe 1992; Collado and Corke, 1996) to reduce production cost and improve nutritive value of food products.

Process of sweetpotato flour

The basic steps of the sweetpotato flour production are the follows: weighing, trimming, washing, peeling, slicing, drying, grinding, sifting, and packaging (Taylor, 1982; Van Hal, 2000). Prior to dehydration, sweetpotato slices can be soaked in water or in solutions containing sodium sulfite, sodium metabisulfite, citric acid, acetic acid to prevent browning.

Quality of sweetpotato flour

Nutritional composition

Sweetpotato flour is a good source of energy. Flour made from orange-fleshed cultivar contains high β-carotene content and reasonable amount of vitamin C, calcium, phosphorus, iron and potassium. Carbohydrate content of sweetpotato flour ranges from 84.6 to 94.8% (db). Total starch content varies from 57 to 90%. Collado (1997) found the significantly negative correlation between starch content and fiber, total free sugar, and ash content among 44 varieties. Sugar content ranges between 6.8 and 23.7%. Protein content is generally low, usually ranging from 1.0 to 8.5% (Van Hal, 2000).

Compared to FAO reference pattern of amino acid, methionine and half-cystine are the most limiting amino acid (Walter et al., 1983). To improve the nutritional value, it has been suggested that sweetpotato flour be used in the combination with other protein-rich ingredients (Van Hal, 2000).

Functional properties

Most information refers to functional properties of sweetpotato starch while the data for those of flour are limited. Flour functional properties are different from those of starch since other constitutuents such as protein, fat, fiber, etc. in flour restrict access of water into the starch granules. Collado (1997) concluded that the pasting parameters of flour were not significantly correlated to the pasting parameters of the purified starch. Therefore, the pasting profile of flour cannot be used to indicate the pasting properties of starch.

Utilization of sweetpotato flour

Sweetpotato flour has a potential to be used in many kinds of bakery products including breads, cakes, cookies, muffins, pies, pretzels and waffles (El-Sahy and Siliha, 1988; Slimak, 1990; Huaman, 1992; Cardenas et al., 1993; Slimak, 1993; Palomar et al., 1994; Savelli et al., 1995; Wanjekeche, 1995). Sweetpotato flour has been used as wheat substitute or composite flour to improve sensory properties of products and reduce wheat imports in many non-wheat grown countries.

In bread products, sweetpotato can be used in both western-style breads such as white bread and French bread (Woolfe, 1992; Cardenas et al., 1993; Savelli et al., 1995) and traditional breads such as balady bread, Indian chaphati and Chinese steam bread (El-Sahy and Siliha, 1988; Woolfe, 1992). Generally, wheat flour can be substituted with 3-15% sweetpotato flour in bread formulation depending on the kinds of breads. However, Cardenas et al. (1993) reported that ground sweetpotato tuber can be used as a substitution of wheat up to 30%. The percent of wheat substitution in other products including cakes, cookies, doughnuts and muffins are different depending on properties of the products. Woolfe (1992) reported that some types of bakery products could be made from 100% sweetpotato flour such as chiffon cake in the Philippines. Generally, 30% sweetpotato flour can substitute in butter cake, cookies and muffins, and 20% sweetpotato flour substitution is possible in doughnuts (Collins and Aziz, 1982; Woolfe, 1992).

Sweetpotato flour can be used as wheat substitute in noodles in the range of 20-70% substitution depending on types of noodles (Woolfe, 1992). Thirumaran and Ravindran (1992) reported that wheat flour was substituted with 50% sweet potato flour to produce vermicelli in India. Collado and Corke (1996) studied the utilization of wheat-sweet potato flour in Chinese style yellow-alkaline noodles and Japanese style white-salted noodles by using 25% sweetpotato flour with different cultivars. They found that noodles produced from composite flour were darker in color and softer in texture than noodles from 100% wheat flour. However, adding ascorbic acid tended to improve noodle firmness.

Collins and Pangloli (1997) studied chemical, physical and sensory attributes of noodles prepared from sweetpotato flour and puree, and defatted soy flour. They concluded that adding sweet potato (10-15%) tended to increase the amount of β-carotene and acceptability in color and texture (stickiness). Defatted soy flour (5-10%) was added in noodle formulation to increase protein content and did not affect acceptability.

Sweetpotato Starch

In Japan, sweetpotato starch has been used in textile, paper and cosmetics industries as an insulating material and adhesives. Sweetpotato starch is also used for the production of noodles (Chiu and Chua, 1989, 1990; Tian et al., 1991; Kim and Wiesenborn, 1996). The basic steps of starch production are follows: washing, adding water, disintegration/crushing, sieving, separation by settling or nozzle separator, concentration by drip-drying in sacks or centrifuge, drying and packing (Woolfe, 1992).

Physicochemical and pasting properties of sweetpotato starch

Starch is a polymeric carbohydrate consisting of α--D-glucopyranose (glucose units) linked together with α--D-(1-4) glucosidic bonds. Starch composes of two major types of polymers: amylose (a linear polymer) and amylopectin (a branched polymer). Sweetpotato starch constitutes up to 70% of dry matter. The physicochemical properties of starch strongly affect the characteristics of cooked products and the potential uses. Physicochemical properties of sweetpotato starch were reviewed by Tian et al. (1991). The shapes of sweetpotato starch granules are oval, round or polygonal with a central hilum. The starch granule sizes range from 7 to 43 μm with the mean size from 12.3 to 21.5 μm. Amylose content varies from 29.4 to 32.2 %. Phosphorous content ranges from 9 to 22%.

Starch pasting properties are responsible for the changes of some food product characteristics during the processing. When starch granules are heated in water to 90 °C or above, gelatinization process occurs resulting in irreversible changes such as breaking of hydrogen bonds, water uptake, swelling, melting of crystallites or helices, birefringence loss, and solubilization (Zobel and Stephen, 1995). These changes are generally accompanied by increasing viscosity and forming a gel on cooling.

The Brabender viscoamylograph is usually used for determining the pasting parameters. Basically, the viscosity changes will be measured as a function of temperature and time. After gelatinization takes place, the viscosity increases because the effect of soluble substances release from swollen starch granules during heating or mechanical disruption. The temperature is usually raised at a rate of 1.5 °C/min, maintained at 95 °C for a 30 min, then cooled at the rate of 1.5 °C/min to 50 °C and held for 30 min (Mazurs et al. 1957; Tian et al, 1991). Pasting parameters can be obtained from amylograph as follows: (a) pasting tempertaure, (b) peak viscosity (highest viscosity), (c) viscosity at 95 °C, (d) viscosity after holding time at 95 °C, (e) viscosity when cooled to 50 °C, and (f) viscosity after holding time at 50 °C.

Viscosity patterns of starch were classified by Schoch and Maywald (1968) as follows: Type A: high swelling starches (i.e. potato, tapioca, waxy sorghum), which show a high pasting peak followed by rapid and major thinning during cooking. Type B: moderate swelling starches (i.e. cereal starches), which show lower pasting peak and much less thinning. Type C: restricted swelling starches (i.e. cross-bonded starches), which show no pasting peak but high viscosity which remains constant or increases during cooking. Type D: highly restricted swelling starches (i.e. starch with more than

55% amylose content), which do not swell sufficiently to give a viscous paste when cooked at normal concentrations. The viscosity profiles of starches as classified by swelling power were shown in Fig. 2.2.

Lii and Chang (1991) reported that the range of gelatinization temperature of sweetpotato starch from Taiwan varieties was between 58 to 69 °C. Sweetpotato starch at 5% concentration showed a type B Brabender viscosity pattern (a moderate peak viscosity and high setback on cooling). However, at 7% concentration, the swelling granules in the paste were too crowded and were rupture easily, then the viscosity increased sharply and then dropped down drastically during the heating stage.

Walter et al. (2000) investigated rheological and physicochemical properties of sweetpotato starch from moist and dry types. Six cultivars including Jewel, Beauregard, and four experimental cultivars (NC10-28, NC2-26, NC6-30, and NC8-22) were studied. The size of the starch granules ranged from 3-60 µm. Amylose content varied from 22.5 to 25.3% by using colorimetric method for determination and from 21.7 to 23.5% by DSC determination. Pasting temperature obtained from Brabender viscoamylograph at 6% w/w starch concentration ranged between 67.0 and 73.8 °C. No peak viscosity was observed from all cultivars. Viscosity during cooking phase increased for some cultivars. Viscosity during cooling phase increased for all cultivars.

Utilization of sweetpotato starch

Sweetpotato starch has been used in noodles, snacks and production of sugars, alcohol, monosoduim glutamate and amino acids (Woolfe, 1992). Sweetpotato starch can be used for making noodles (Chiu and Chua, 1989, 1990; Kim and Wiesenborn, 1996).

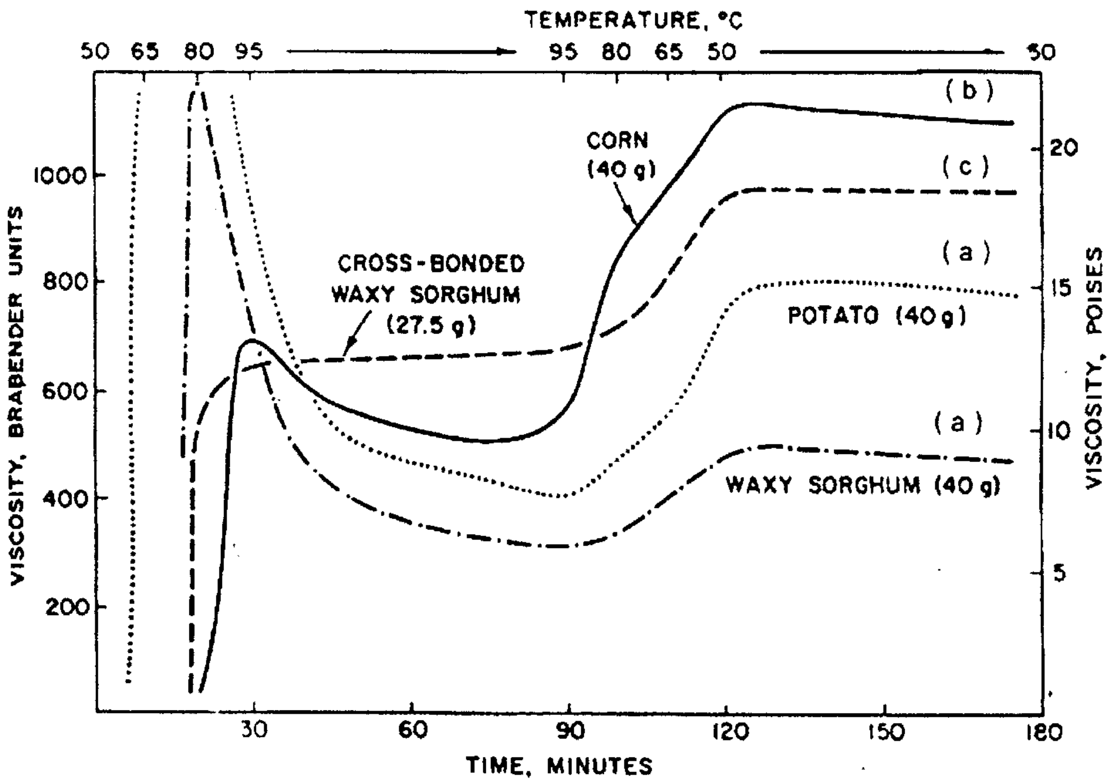

Fig. 2.2. Viscosity profiles of starches as classified by swelling power (Leach, 1965)

The process of making starch noodles is as follows: adding water at a temperature higher than 80 °C into starch to gelatinize starch, adding sulphite and native starch, mixing, passing through holes, receiving strings in hot water, stringing to cold water and drying (Woolfe, 1992).

Kim and Wiesenborn (1996) reported that sweetpotato starch has a potential to produce starch or "glass" noodles. However, cooking quality and sensory attributes were lower than typical mung bean starch noodle.

Methods of modified starch

The reasons for modifying starch are to improve the functional properties of starch and to expand the usefulness of starch so it can be cooked at the higher concentration than unmodified starch (Wurzburg, 1986). The modification methods can be classified as chemical and physical modification. Chemical modification includes conversion, crosslinking and substitution while physical modification includes pregelatinization and heat treatment (Thomas and Atwell, 1999).

The chemical modification of starch is usually performed in an aqueous medium. Starch suspension, typically 35-40% (by weight), is treated with chemical reagents under proper agitation, temperature, and pH. When the reaction is complete, the starch is brought to the desired pH by neutralizing agent and then purified by washing with water and recovered as a dry powder (Thomas and Atwell, 1999). Chemicals used depend on the modification method; for example, sodium hypochlorite is used for production of oxidized starch.

Pasta and Noodles

Pasta is the most common paste-product made from durum wheat. Pasta is generally referred to “Italian” style of extruded products such as spaghetti, macaroni or lasagne, and is distinguished from the “Oriental” style pasta made from wheat other than durum, which is called noodles. However, those definitions are confused by the type of pasta which is called noodles. Pasta noodles in the U.S. are made from durum or non-durum wheat and are required to contain a minimum of 5.5% egg solids. Therefore, the best way to minimize the confusion in terminology of these paste products is to call all of them “pasta” and differentiate among them by their specific formulation, manufacturing process, shape, and specific name (Dick and Matsuo, 1988).

Classification of pasta and noodles

European style pasta

Good quality pasta is preferably made from durum wheat semolina (*Triticum durum*). Semolina and water (approximately 30%) were mixed to a dough, extruded through a die (usually made of brass with teflon inserts), and dried at 70-90 °C to 11-13% of moisture content (Miskelly, 1993).

Italian traditional pasta can be categorized into four groups: (1) long-goods (i.e., spaghetti, vermicelli, and linquine), (2) short-goods (i.e., elbow macaroni, rigatoni, and ziti), (3) egg noodles, (4) specialty items (i.e., lasagne, mamicotti, jumbo shells and stuffed pasta) (Dick and Matsuo, 1988).

Dried pasta can be classified into different categories based on the future market trends as the follows: (1) Wheat pasta, made from durum semolina or soft wheat, (2) Egg pasta, (3) Whole meal pasta, made from whole meal semolina or flour, (4) Pasta altered in its nutrition value (e.g. enriched with protein or dietary fiber), (5) Pasta made from non-bread cereal grains (e.g. corn, buckwheat, millet), and (6) Dietary pasta products such as gluten-free pasta made without wheat, rye, oats, barley (Seibel, 1996).

In addition to the dried pasta, fresh pasta receives more attention because the consumers realize the better quality of fresh products and quicker preparation. However, this type of pasta should be kept in refrigerator or kept frozen due to the high moisture content may cause the microorganism spoilage (Seibel, 1996).

Asian style noodles

Products are classified according to major ingredients and method of manufacture. Major ingredients include wheat flour, rice flour, and starch from bean, potato, and corn. Major manufacture methods depend on presence or absence of gluten. Wheat flour noodles can be produced by sheeting and rolling method while others can be made by extrusion or batter cooking methods (Miskelly, 1993).

Pasta process

Conventional pasta process

Regular wheat pasta can be made simply by mixing wheat semolina or flour with water, extruding into pasta shapes and drying. Water is mixed with semolina or flour to produce a dough with a moisture content of 30-34% (Matz, 1991; Dalbon et al., 1996). The products are typically produced by extrusion with automatic machines that perform several processing including mixing, kneading, and extruding. The extruded products are dried to approximately 12.5% moisture content and then packaged (Giese, 1992).

Non-conventional pasta process

Due to the lack of gluten in non-conventional raw materials, pasta meeting product requirements cannot be made from them by the conventional process. Gluten is the wheat protein that contributes pasta with good firmness and low cooking loss to pasta. Three approaches have been suggested to yield a good quality product. The first possibility is to set up technologies using the functional properties of other components of the raw material such as starch. The second possibility is to provide suitable quantities of protein fortifying flours whose proteins are able to organize as gluten does. The third possibility is to add particular additives such as mono and diglycerides (forms a complex with amylose and prevents the passage of starch into cooking water), carageenans, alginates, gums, fatty acids, and ascorbic acid (Pagani, 1986).

The production technology of non-wheat pasta has to promote particular structures in starch. The process requires the high temperature treatment (90-95 °C) of a fraction of the dough starches or flours. This fraction is then mixed with the rest of the ingredients. The heated starch or flour behaves as a binder, which repolymerizes into a network like that found in starch noodles (Pagani, 1986).

An alternative method requires a precooking process to gelatinize the flour or starch in order to obtain a firm pasta structure. The precooking may be carried out by either boiling or steam cooking. Steam cooking usually requires 40-50% dough moisture for efficient cooking but at this moisture range the dough is too sticky for extruding of rice pasta (Hsu, 1984).

Evaluation of cooked pasta quality

Cooking quality

Cooking quality of pasta is the most important factor for consumer acceptance. These characteristics include cooking time, swelling (i.e., cooked weight or rehydration), texture of cooked pasta (i.e., firmness), surface condition (i.e., stickiness), and aroma and taste (Feillet and Dexter, 1996).

Cooking loss is a parameter used as an indicator of overall cooking performance. It is related to the breakdown of pasta during cooking (D'Egidio and Nardi, 1996). Cooking loss can be determined by weighting the residue of cooking water after evaporation by drying (AACC, 1985) or after freeze-drying (Dexter and Matsuo, 1979).

Color

Color is important to pasta product because it is the first quality parameter perceived by the consumer at point of sale. Color can be measured visually (subjective method) and/or instrumentally (objective method). Subjective methods may be used alone or combination with instruments.

Instruments for color measurement include the Agtron reflectance spectrophotometer (Magnuson Engineer Inc., San Jose, CA), Hunter color difference meter (Hunter Associates Laboratory, Reston, VA), and Minolta chroma meter (Minolta Corp., Japan) (Miskelly, 1996).

The yellow color of pasta is related to the carotenoid pigments. Factors affecting pasta color include wheat characteristic, milling conditions (i.e., extraction rate), and pasta process conditions (i.e., hydration, mixing, extrusion and drying). These factors can promote or deter oxidation and affect the destruction of carotenoid pigments, and resulting in bleaching of pasta color mediated by lipoxygenase (Feillet and Dexter, 1996).

Texture

The textural characteristics of cooked pasta play an essential role in determining consumer acceptance. It is generally accepted that the main criterion for assessing overall quality of cooked pasta is based on evaluation of texture. Texture attributes can be measured by objective methods and sensory evaluation.

In general, the instrumental tests are based on measurement of tension, compression, adhesion or combination of these factors (D'Egidio and Nardi, 1996). A number of instrumental methods have been developed to measure cooked pasta texture parameters (Voisey and Larmond, 1973; Voisey et al., 1978; Dexter et al., 1983; Oh et al., 1983; Edwards et al., 1993; Guan and Seib, 1994; D'Egidio and Nardi, 1996). The texture parameters can be measured by using instruments such as Instron Universal Testing Machine and TA-XT2 texture analyzer.

The texture attributes of cooked pasta are defined as follows (D'Egidio and Nardi, 1996):

Firmness (or hardness): defined as the degree of resistance to the first bite or the force required to penetrate pasta with the teeth.

Cohesiveness (or consistency): defined as the force of internal bonds holding the pasta structure.

Elasticity (or springiness or recovery): defined as the capacity of a deformed pasta to go back to its initial condition when the deforming force is removed.

Stickiness (or adhesiveness): the force with which the cooked pasta surface adheres to other materials such as tongue.

Protein sources

Soy protein

Soybean (*Glycine max* (L.) Merrill), a native of China, has been used as an important protein source in oriental countries including Japan, Korea, and Southeast Asian countries for centuries. Recently, soy products gained a lot of attention from the western consumers because of many health benefits. In 1999, the U.S. Food and Drug Administration (FDA) allows a health claim for soy protein on food labels stating that a daily diet containing 25 grams of soy protein, also low in saturated fat and cholesterol, may reduce the risk of heart disease. To qualify for the health claim, foods must contain at least 6.25 grams of soy protein per serving and fit other criteria, such as being low in fat, cholesterol, and sodium (Henkel, 2000). Soybean is also a concentrated source of isoflavones, which have potential role in preventing and treating cancers and osteoporosis (Messina, 1999).

There are several types of soy protein products including defatted soy flakes and meal, defatted soy grits and flour, soy protein concentrate, soy protein isolate, full-fat soy flour, enzyme active soy flour, and textured soy protein (Liu, 1997). Among soy protein products, soy flour, soy protein concentrate, soy protein isolate, and textured soy protein have been used as functional ingredients in many types of foods such as bakery, meat, soup and pasta. Soy flour or grits are prepared from defatted soybean flakes and produced in a variety of particle sizes. The protein content ranges from 40-54% on a moisture-free basis. Soy protein concentrate is prepared from defatted and dehulled soybeans and contains no less than 65% protein on a moisture-free basis whereas soy protein isolate contains no less than 90% protein on a moisture-free basis (Messina, 1997).

Nutritional quality of soy protein

Amino acid composition of soy flour, soy concentrate and soy isolate generally meets the Food and Nutrition Board (FNB) pattern requirement for infants. Soy protein is rich in lysine, a limiting amino acid in cereals, and contains all essential amino acids in sufficient quantities except for the sulfur-containing amino acids, cysteine and methionine (Liu, 1997).

Nutritive values of soy protein depend on amino acid bioavailability or protein digestibility. The factors affecting protein digestibility include internal factors (i.e., levels of antinutritional factors and protein structure) and external factors (i.e., heat treatments and purification process). Antinutritional factors in soybean such as trypsin inhibitors, lectins, phenolics and phytin decrease the digestibility of protein (Bradford and Ortheofer, 1983; Liu, 1997). Heat treatment improves protein digestibility by inactivation of trypsin inhibitors and other antinutritional factors. Compared to soy flour, soy isolate has higher protein digestibility because of more protein purification. Reduction of disulfide bonds, which maintain protein structure and stability, leads to increased susceptibility to proteolytic reaction by enzyme. Hence, the protein digestibility increases (Hettiarachchy and Kalapathy, 1997).

Whey protein

Whey is a by-product from manufacture of cheese. It is a collective term referring to the serum or watery part of milk that remains after the cheese process. Whey can be transformed into a dry product by different techniques, and the quality of the product varies with the technology applied.

Whey products can be classified into several categories including acid whey, sweet whey, whey protein concentrate (WPC), whey protein isolate (WPI), reduced-lactose whey, and demineralized whey. Acid whey is produced during the manufacture of cottage and ricotta cheeses and has a pH less than 5.1. Sweet whey has a pH 5.5 or greater and is obtained during the manufacture of rennet-coagulated cheese (cheddar or swiss cheese). WPC is manufactured by drying material obtained from filtering out non-proteins from pasteurized whey, and used to enhance protein content and functionality of food products. WPC typically contains 34% or more protein. WPI is produced similar to WPC, but contains 90% or more protein. Reduced-lactose whey contains less than 60% lactose content. Demineralized whey is made by drying whey that a portion of minerals has been removed, and cannot contain more than 7% ash content (DMI, 2001a).

Nutritional quality of whey protein

Whey proteins are easily digested and contain an amino acid profile that meets or exceeds all essential amino acid requirements set by the Food and Agriculture Organizaton/World Health Organization (FAO/WHO). Compared to wheat gluten and soy protein, whey protein concentrate has higher protein efficiency ratio (PER) (Swartz and Wong, 1985). It also has the high content of the amino acid tryptophan, a precursor of vitamin niacin. Niacin functions as part of coenzyme in fat synthesis, tissue respiration and utilization of carbohydrate. This vitamin promotes healthy skin, nerves and digestive tract, aids in digestion and fosters a normal appetite (DMI, 2001b).

The major whey proteins are β-lactoglobulin and α-lactalbumin. The minor whey proteins include proteose-peptones, blood protein and lactoferrin. These components can provide passive protection against infection; modulate digestive and metabolic processes; and act as growth factors for different cell types, tissues and organs. Whey products improve the host antioxidant defenses and lower oxidant burden because of containing active lactoferrin/metal-binding activities. Whey products can be used to enhance the significant mineral nutrients including calcium, magnesium and phosphorus in other food products (Walzem, 1999).

Vital wheat gluten

Wheat gluten is a unique protein which is responsible for the viscoelastic properties of dough. Gluten is prepared by mixing wheat flour with an appropriate amount of water into a dough and washing out the starch and soluble matter under a stream of water. The “wet gluten” is obtained, then it is carefully dried and ground to a “vital wheat gluten” (Bushuk and Wadhawan, 1988). Vital wheat gluten typically composes of 75% protein, 6% moisture, 1% ash, and 1% fat. The major protein components in gluten can be seperated into two fractions: gliadin, which is an alcohol soluble fraction, and glutenin, which is insoluble in alcohol. Gliadin and glutenin differ in their physical properties, especially their viscoelasticity. Gliadin is cohesive, but low elasticity, whereas glutenin is both cohesive and elastic. Gliadin is composed of proteins of relatively low molecular weight (MW) in comparison with the high MW proteins of glutenin fraction. These fractions also differ slightly in amino acid composition: gliadins tend to have larger amounts of proline, glutamic acid plus glutamine, cystine, isoleucine, phenylalanine, and amide nitrogen than glutenin, whereas glutenin has larger amounts of glycine, lysine, and tryptophan (Bushuk and Wadhawan, 1971).

Nutritional quality of vital wheat gluten

The amino acid composition of gluten is typical of cereal storage proteins, characterized by the relatively high contents of glutamine, proline and hydrophobic amino acids, and low contents of amino acids with ionizable size groups. The low content of polar groups gives gluten proteins a resultant positive eletrostatic charge compared with most other proteins, which have a net negative charge. Wheat gluten is a most unique protein in terms of amino acid composition. However, wheat gluten alone ranks low in the scale of nutritional quality because of its low lysine content (Bushuk and Wadhawan, 1988).

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CHAPTER 3

DEVELOPMENT OF A NEW PASTA PRODUCT USING SWEETPOTATO FLOUR SUPPLEMENTED WITH TAPIOCA FLOUR, WHEAT GLUTEN, WHEY PROTEIN CONCENTRATE AND DEFATTED SOY FLOUR[1]

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ABSTRACT

Pasta made from sweetpotato flour, a domestic cultivar (Beauregard) with deep orange flesh, was fortified with two protein sources: wheat gluten (10%) or whey protein concentrate (10%) and tapioca flour at the levels of 0, 10, 20, 30%. Pasta was made by extrusion using a pilot plant scale pasta machine. The sweetpotato flour was also chemically modified using a treatment with 4% sodium hypochlorite solution. The modified sweetpotato flour (MSPF) was mixed with untreated sweetpotato flour (SPF) and/or defatted soy flour (DSF) at levels of 0, 15, and 30% each and then steam-cooked. Sweetpotato pasta fortified with 10% whey protein concentrate and 30% tapioca flour had lower cooking loss (9.9%) and higher shear force (576.4 N) than those (13.8% and 455.5 N, respectively) of pasta without tapioca supplementation. Pasta made from 100% MSPF had the lowest cooking loss (5.6%) and the highest firmness (1.9N) among samples. Addition of tapioca flour and DSF in sweet potato flour increased the lightness (L*) and decreased the redness (a*) of cooked pasta.

INTRODUCTION

Sweetpotatoes, containing high levels of carbohydrates, carotenoids, fiber, vitamins and minerals, are a staple food for some countries including Papua New Guinea and the Phillippines (Villareal et al., 1982; Yang, 1982). Options for sweetpotato products are numerous, but usually based on dried chips, starch and flour (Van Hal, 2000). Many snack products made from sweetpotatoes are available in the markets, for example, sweetpotato chips become popular in China, Japan and Peru (Woolfe, 1992). Sweetpotato starch has been used for production of noodles (Chiu and Chua, 1989, 1990; Tian et al., 1991; Kim and Wiesenborn, 1996); however, sweetpotato flour has only been used as a minor ingredient in noodles formulations (Collado and Corke, 1996; Collins and Pangloli, 1997).

In recent years, the U.S. pasta consumption has been increased and rapidly growing (Giese, 1992; Pszczola, 2000). Varieties of pasta are available in the markets. Although starch, isolated from sweetpotatoes, has been used for producing pasta products, the nutrients including carotenoids, fiber, and minerals in the flour were lost. Sweetpotato flour made from orange-fleshed roots contains high level of β-carotene; however, the whole sweetpotato flour is difficult to use due to its poor pasting property.

Development of non-wheat pasta products has received a considerable amount of attention since various raw materials (i.e., rice, potato, maize, and legumes) can be used for pasta production. However, these “non conventional” raw materials are difficult to make pasta by using traditional method. Three possible solutions have been raised to solve this problem including new technologies (i.e., extrusion cooking and high temperature drying), addition of selected additives, and fortification with proteins able to form complexes similar to gluten (Pagani, 1986; Giese, 1992). In order to improve the flour quality for production of pasta from the whole sweetpotato. The objectives of this study were to develop a pasta product by adding ingredients such as tapioca, defatted soy flour, whey protein in formulations or modifying sweetpotato flour as a major ingredient and to examine the quality of cooked product.

MATERIALS & METHODS

Preparation of sweetpotato flour

Sweetpotato flour was prepared from sweetpotato roots (*Ipomoea batatus*) of deep orange color and jumbo size of Beauregard cultivar, which were purchased from Leeland Farm in Leesberg, GA. The roots were washed, hand-peeled and sliced to a 2-mm thickness. Slices were soaked in 0.1% sodium metabisulfite before drying at 70 $^{\circ}$C for 12 hrs. The dried sweetpotato chips were ground by using a Super Masscolloider (Masuko Sangyo Co., Ltd., Japan) and sifting by using Sweco Seperator (Sweco, Inc., Ft. Smith, Ark, USA) to pass through 80 mesh sieve. The flour was then vacuum-packaged in cryovac bags and stored at -18 $^{\circ}$C until used.

Ingredients used in this study include: defatted soy flour (Soyafluff®200W, Central Soya Company, Inc., Fort Wayne, IN); wheat gluten (FP™ 6000, Midwest Grain Products, Inc., Atchison, Kansas); whey protein concentrate (Alacen 878, New Zealand Milk Products (North America), Inc., Santa Rosa, California); tapioca flour (First World Imp & Exp Co., Ltd, Bangkok, Thailand); xanthan gum (Bob's Red Mill®, Natural Foods, Inc., Milwaukie, Oregon); monoglyceride (Starplex® 90, American Ingredients company, Kansas City, Missouri); and ascorbic acid (Food Grade, Fisher Scientific, Fair Lawn, New Jersey).

Modification of sweetpotato flour

Prepared sweetpotato flour was chemically modified by using the method modified from Forsell et al. (1995). The flour was suspended as a 20% (dwb) suspension and adjusted to a pH of 10.5 with 2 M NaOH solution. Sodium hypochlorite solution (4% NaOCl, Activity 1000 ppm Cl/Kg flour) was added to the stirred slurry for 3 hrs, and then the pH was then adjusted to 7.0 with 1 M sulfuric acid. Finally, the excess chloride in slurry was destroyed by adding 0.1% sodium bisulfite (w/w). The suspension was then vacuum filtered, washed twice with distilled water, dried at 50 °C overnight and ground by using Ultra Centrifugal Mill Model ZM 100 (F. Kurt Retsch GmbH & Co., Haan, Germany) to pass through 0.5 mm screen.

Pasta Formulation

Ingredients used in formulation were based on 100% of the solid content with constant levels of 10.0% wheat gluten (WG) or 10.0% whey protein concentrate (WPC), 2.0% xanthan gum, 0.1% ascorbic acid, and 0.5% monoglyceride. The experimental samples were prepared according to the basic formulation with a portion of sweetpotato flour replaced with tapioca flour (TF) at 0, 10, 20, and 30%. The calculated amounts of sweetpotato flour were 87.4, 77.4, 67.4, and 57.4%, respectively. The water was added to yield a dough with a final moisture content of approximately 35%.

For modified sweetpotato pasta study, nine formulations of pasta (Table 3.1) were obtained from the Mixture Design (Cornell, 1981). Each formulation is composed of three components: (a) Sweetpotato flour (SPF), (b) Modified sweetpotato flour (MSPF), and (c) Defatted soy flour (DSF). SPF and DSF at the levels of 0, 15, and 30% were used to replace MSPF in the flour mixture. Three replicates were done for all formulations.

Preparation of pasta

Pasta samples were prepared using extrusion and steaming methods.

(a) Extrusion method:

A pilot plant scale pasta maker (Model pasta MAKR V, The Bonnet Co., Ohio) was used for preparation of pasta samples. A die with 0.8 x 20 mm aperture was used to produce flat noodles. The extruded samples were dried in a convection oven at 50 °C for 8 hrs to the moisture content approximately 10%.

(b) Steaming method:

A mixture of flour was prepared as a 20% (db) suspension. The slurry (50 gm) was put in an 8" diameter pan and steam-cooked by using steamer with boiling water for 4 min. The pasta sheet was removed from the pan, cut into 0.6 mm width by using a noodle maker machine (Atlas®, model 150, Italy) and then dried at 50 °C for 4 hrs. The thickness of dried pasta was approximately 1 mm.

Proximate composition of ingredients

Proximate composition of samples was determined by AOAC (1997) methods as follows: moisture by the vacuum oven method 925.09; ash by the muffle furnace method

923.03; crude protein by Kjeldahl method 960.52; crude fat by Petroleum ether extraction method 920.85 (using 6.25 as conversion factor); and carbohydrate by subtracting percentage of other solids from 100%. Crude fiber was determined by method 962.09.

Color measurement

The color of ingredients and cooked pasta was measured using a hand-held Minolta Chroma meter (Model CR-200, Minolta Corporation, Japan). Sample of cooked pasta was placed in the sample cup for measurement. Color values were recorded as "L*" (lightness), "a*" (redness), and "b*" (yellowness). From a* and b* values, the hue angle ($\tan^{-1} b^*/a^*$) and chroma ($((a^{*2}+b^{*2})^{1/2})$) were calculated. Each sample was measured three times.

Cooking loss

Cooking loss was measured by AACC Method (1995) with modification. Samples (5 gm) were boiled in a beaker of 200 ml distilled water for 4 min and rinsed with 50 ml distilled water and then drained for 5 min. Both cooking and rinsing water was collected and dried in an air oven at 100 °C for 20 hrs. The remaining solids were weighed to determine cooking loss, which was expressed as percentage of initial dry matter. Samples of cooked pasta were weighted to determine cooking yield.

Texture analysis of cooked pasta

The firmness of cooked pasta was measured using an Instron Universal Testing Machine (Model 1122; Instron Corporation, Canton, MA) equipped with a 500 kg load cell and a Kramer shear compression cell. A sample of 75 gm cooked pasta was placed in the Kramer shear compression cell. Testing parameters for analysis were set at 50 mm/min crosshead speed. The maximum forces required to shear the sample were recorded. All treatments were done in triplicates.

For cooked pasta made from modified sweetpotato flour, the firmness was measured using an Instron Universal Testing Machine Model 1122 (Instron Corporation, Canton, MA) equipped with a 50 N load cell and a cutting plexiglass blade (AACC method, 1995). Three strands of cooked pasta were placed on a sample holder parallel to each other. Testing parameters for analysis were set at 5mm/min crosshead speed. The maximum forces required to shear the sample were recorded. All treatments were done in triplicates.

A texture profile analysis (TPA) was conducted to determine adhesiveness (stickiness), cohesiveness and springiness of cooked pasta using methods of Voisey et al. (1978) and Tang et al. (1999) with modification. Three strands of pasta were placed on a sample holder, which had a 90 degree grooves surface, and compressed to 75% of the depth of pasta with a flattened cylinder aluminum plunger (5.5 cm diameter) using 5 mm/min crosshead speed. On the force-time curve, adhesiveness was defined as the negative force area after the first compression, representing the work necessary to pull the compressing plunger away from the sample. Cohesiveness was defined as the ratio of the area under the second peak to the area under the first peak. Springiness was defined as the distance at which a deformed sample went back to its non-deformed condition after the deforming force is removed during the second compression.

Cooking characteristics of commercial pasta

The experimental pasta products obtained from the best formulation using both extrusion and steaming method were compared to the commercial pasta products. Commercial wheat noodle (Iron-Man®, Great Wall Enterprise Co., Ltd., Taipei, Taiwan) had the dimension of 0.6 mm width x 1.0 mm thickness while rice noodle (Asian Best®, Eastland Food Co., Bangkok, Thailand) had the dimension of 0.4 mm width x 1.2 thickness. Color, cooking loss, cooking yield and firmness of cooked pasta were measured using the method described above.

Statistical Analysis

General Linear Models (GLM) procedure was used to analyze the means values of pasta quality data from each treatment. Where significant differences were found, means were separated using the least significant difference (SAS Institute, 1989).

RESULTS & DISCUSSION

Proximate composition of ingredients

Proximate compositions of main ingredients were compared in Table 3.2. SPF, TF, and MSPF contained high levels of carbohydrate of 90.1, 99.1, and 95.0 % (db), respectively; however, the starch content of SPF was only accounted for 51.9 % (db). The rest of carbohydrate contents (38.3 %db) included sugar and fiber contents. The protein contents of SPF, TF, and MSPF were 5.7, 0.1, and 1.5% (db), respectively. Pasting properties of starch and quantities and qualities of protein are important factors to the quality of noodles (Huang and Morrisson, 1988; Konik et al., 1992). Since SPF contained low amount of protein, WG, WPC and DSF (90.0, 83.0, and 52.0% (db) protein, respectively) were used to fortify the pasta.

All ingredients contained low fat content (0.6-4.6% db). The ranges of protein content of dried pasta fortified with 15% and 30% DSF at 0, 15, 30% SPF were 9.6-10.2% (db) and 17.2-18.8% (db), respectively. Protein content of pasta fortified with 15% and 30% DSF increased up to 6 and 11 times, respectively, as compared to pasta made from 100% MSPF (1.7% db).

Color of ingredients

The color values of dried ingredients were shown in Table 3.3. SPF and MSPF had higher in a*, b* and chroma, but lower in L* and hue angle than TF and DSF. Hue angles of SPF and MSPF were 65.4 and 64.4, respectively, indicating an orange color, whereas hue angles of TF, WG and WPC ranged 87.0 – 97.0 indicating a white and cream color. This implied that SPF and MSPF contained higher carotenoid pigments than ingredients.

Cooking characteristics of pasta made by using extrusion process

Color

Lightness (L*) values were significantly affected by protein sources (WG and WPC) and tended to increase with the increasing levels of TF (Table 3.4). Addition of tapioca flour and protein affected the color of cooked sweetpotato pasta (Table 3.5). The mean “L*” values of sweetpotato pasta fortified with WPC was 62.9 while that of pasta fortified with WG was 58.4 (Table 3.4). Hue angle significantly increased with the addition of TF (Table 3.5). The linear trend of hue angle among the levels of TF was highly significance ($p < 0.01$). At level of 0% TF, hue angles of pasta fortified with WG and WPC were the lowest (76.1 and 75.5, respectively) (Table 3.4). When the amount of added TF increased to 30%, hue angles of pasta fortified with WG and WPC were the highest (79.5 and 77.7, respectively). This result indicated that the redness of cooked pasta tended to decrease as the levels of TF increased. This could be explained by the color properties of sweetpotato and tapioca flour. SPF contained carotenoids and possibly anthocyanin, which form color that affect the red-green chromaticity (Collado et al., 1997). Increasing the levels of TF tended to decrease the color pigments in SPF resulting in increasing the hue angles of pasta. Both types of protein had no effect on hue angle, but had the effect on the chroma of cooked pasta (Table 3.5). Pasta fortified with WPC had higher chroma or more color intensity than pasta fortified with WG (Table 3.4). This may due to the different color properties of those proteins as shown in Table 3.2.

Cooking loss

Pasta fortified with 10% WG had highest cooking loss (14.8%) without adding TF while that with 30% TF addition had the cooking loss of 11.0% (Table 3.4). However, the pasta fortified with 10% WPC and 30% of addition of TF had the lowest cooking loss (9.9%). The linear trend of cooking loss among the levels of TF was highly significance ($p < 0.01$). Addition of tapioca flour up to 30% significantly decreased cooking loss of sweetpotato pasta fortified either with 10% WG or 10% WPC (Table 3.5). These results implied that the pasting properties of tapioca starch could affect the cooking loss. Starch provides the structure of the product when starch is gelatinized and forms the gel matrix. Addition of tapioca flour increases the proportion of starch fraction, which is associated with high paste viscosity (Collado and Corke, 1996; Oda et al., 1980).

Cooking loss of pasta also significantly affected by types of protein sources (Table 3.5). Cooking losses of pasta fortified with 10% WPC was lower than those of pasta fortified with 10% WG. The mean cooking loss of sweetpotato pasta fortified with WPC was 11.6% while that of pasta fortified with WG was 13.0%. Kadharmesta (1998) reported that the cooking loss of cantonese noodles fortified with 5 or 10% commercial WPC was smaller than 13.0% and comparable to or lower than that of control noodles without adding whey protein concentrate.

Firmness

Firmness of sweetpotato pasta fortified with WG and WPC was increased with the increasing level of tapioca flour (Table 3.4). At level of 0% TF, the firmness of pasta fortified with 10% WG was lowest (330.6 N). When the amount of added TF increased to 30%, the shear force increased (427.0 N). The firmness of pasta fortified with 10% WPC but no TF addition was 455.5 N while the firmness of pasta at 30% addition of TF was highest (576.4 N).

Firmness of pasta fortified with 10% WPC was higher than those of pasta fortified with 10% WG. Types of protein sources (WG and WPC) and level of TF significantly affected the firmness of sweetpotato pasta (Table 3.5). Kadharmesta (1998) stated that the hardness of cantonese noodles fortified with commercial WPC was statistically higher compare to the control sample due to the low water absorption of flour fortified with WPC. In addition, sulfur containing amino acid in whey protein may react with ascorbic acid, a dough improver in wheat products, resulting in forming of disulfide bond and firmer texture. Although pasta fortified with WPC had higher firmness, the product was less elastic than pasta fortified with WG.

Cooking characteristics of pasta made by using steaming process

Color

Addition of DSF (0-30%) significantly increased L* and hue angles, but decreased a* of cooked pasta; however, DSF did not affect b* and chroma. The hue angles ranged from 58.9 to 65.5 indicated that pasta had orange color (Table 3.6). The yellow-orange color of sweetpotato flour was caused by the presence of carotenoid pigments, which affected the red-green chromaticity (Callado et al., 1997; Van Hal, 2000). Supplementation of DSF (cream color) tended to reduce the corotenoid pigments of SPF. Fortification of pasta with DSF significantly affected the color of cooked products (Table 3.7).

Cooking quality of pasta

Cooking loss was used as a parameter to indicate the overall cooking performance and related to the breakdown of pasta during boiling (D'Egidio and Nardi, 1996). Pasta made from 100% MSPF or supplemented with 15% and 30% DSF had lower cooking loss (5.6%, 6.7%, and 8.5%) and higher cooking yield (335.7%, 346.8%, and 344.2%) (Table 3.8). Cooking loss increased to 13.4-15.4% and 18.4-20.2% as the levels of SPF increased to 15% and 30%, respectively. Cooking loss significantly increased as levels of SPF increased (Table 3.9). However, there was no significant difference of losses among the levels of DSF (Table 3.9). The high cooking loss indicated that pasta fortified with SPF and DSF was more broken down during cooking than pasta made from 100%MSPF. The cooking quality of non-conventional pasta with absence of gluten should depend on the pasting properties of starch. When starch granules imbibed water under applied heat, the irreversible changes would occur including the disruption of semicrystalline structure, as evidenced by a loss of birefringence, and increase in granular size. As heating continued, more granules became swollen and disrupted and released of amylose resulting in increase of viscosity of medium and became a paste or gel matrix when the medium was cooled (Thomas and Atwell, 1999). Thus, starch functions as the network that maintains structure during cooking. The network swells during cooking because of the hydration of the amorphous regions. The deformation of the network causes the amylose to be released and increasing of cooking loss (Mestres, 1988). Collins and Pangloli (1997) reported that addition of 10-15% sweetpotato and soy flour in wheat noodles increased cooking loss of products. Cooking yield decreased with the increasing level of sweetpotato flour (Table 3.9). No significant difference of cooking yields among levels of DSF in each level of SPF was observed.

Texture of cooked pasta

Firmness of sweetpotato pasta decreased from 1.9 to 0.9 N (Table 3.8) as the levels of native SPF and DSF increased. Pasta made from 100% MSPF had highest firmness (1.9 N). Addition of DSF at 15 and 30% with no SPF substitution decreased the firmness to 1.3 and 1.2 N, respectively. Addition of SPF and DSF significantly decrease firmness of cooked pasta (Table 3.9).

Stickiness is an important negative quality factor of cooked pasta. Good quality pasta should be less stickiness. The measurement was conducted by using sample holder with surface serrated by 90 degree grooves, which made pasta adhere more strongly to the lower surface after it was compressed. Thus, the adhesion forces between the pasta and smooth surface top plate could be measured under controlled condition (Voisey, 1978). The result showed no significant difference on stickiness values among treatments was observed (Table 3.9). Cohesiveness and springiness tended to decrease from 0.67 to 0.53 and 0.85 to 0.69mm (Table 3.8), respectively, as the level of SPF and DSF increased. This may be due to the starch network and pasting behavior. Addition of SPF and DSF reduced the viscosity of mixture suspension and disturbed the gel matrix. Therefore, the firmness, cohesiveness and springiness decreased when the levels of SPF and DSF were substituted.

Cooking characteristics of commercial pasta

Color, cooking quality and firmness of commercial wheat and rice noodles were determined to compare with our experimental pasta products. Cooking characteristics of cooked pasta were shown in Table 3.10. Sweetpotato pasta had yellow-orange color while wheat and rice pasta had pale yellow and white color, respectively. Wheat and rice noodles had lower cooking losses than experimental pasta made by using either extrusion and steaming method. Pasta made from sweetpotato and tapioca flour fortified with 10% WPC was easy to cook (less cooking time); however, the texture was softer than wheat pasta, which required longer cooking time. The pasta made from 100% modified sweetpotato flour had higher cooking yield and the same cooking time as rice noodle, but the pasta firmness was slightly lower.

Correlation among cooking characteristics of sweetpotato pasta

Correlation among cooking quality characteristics were analyzed (Table 3.11). Cooking loss was negatively correlated with cooking yield (cooked weight) ($r = -0.78$, $p<0.01$), firmness ($r = -0.68$, $p<0.01$), and cohesiveness ($r = -0.76$, $p<0.01$). Thus, cooking loss increased as cooked weight, firmness, and cohesiveness decreased. The correlation coefficients among cooking qualities of cooked potato starch noodles were reported by Kim and Wiesenborn (1996). They reported that firmness was correlated to cooking loss ($r = -0.52$) and cooked weight ($r = -0.82$) at $p<0.01$.

The correlation between firmness and cooking loss was negative ($r = -0.68$, $p<0.01$), but the correlation between that with cohesiveness ($r = 0.66$, $p<0.01$), and springiness ($r = 0.45$, $p<0.05$) was positive. Stickiness was negatively correlated with cooking yield ($r = -0.42$, $p<0.05$) and springiness ($r = -0.39$, $p<0.05$). Cohesiveness was positively correlated with cooking yield, firmness and springiness, but negatively correlated with cooking loss.

CONCLUSION

The results in this study showed addition of 30% TF for sweetpotato pasta fortified with 10% WG or 10% WPC produced a product that had low cooking loss and high firmness with an orange natural color. WPC could be substituted in pasta formulation and yielded the product with similar quality as using WG. Pasta fortified with 10% WPC at 30% addition of TF had lowest cooking loss and highest shear force.

Modification sweetpotato flour is a better material for making pasta as compared to native sweetpotato flour. Pasta products can be produced from 100% MSPF with the lowest cooking loss and the highest firmness. Supplementation of up to 30% DSF to pasta formulation not only enhanced the nutritive values of sweetpotato pasta but also produced a product with similar cooking quality, stickiness, cohesiveness and springiness as compared to using 100% modified sweetpotato flour.

ACKNOWLEDGMENT

We thank Dr. Klanarong Sriroth, Head of Cassava and Starch Technology Research Unit, National Center for Genetic Engineering and Biotechnology, Thailand, for his advice in modification method of flour.

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Table 3.1. Formulations of sweetpotato pasta containing modified sweetpotato flour (MSPF), Sweetpotato flour (SPF), and Defatted soy flour (DSF)

Formulations	MSPF (%)	SPF(%)	DSF (%)
1	100	0	0
2	85	0	15
3	70	0	30
4	85	15	0
5	70	15	15
6	55	15	30
7	70	30	0
8	55	30	15
9	40	30	30

Table 3.2. Proximate composition of major ingredients of pasta (Sweetpotato flour (SPF); Tapioca flour (TF); Wheat gluten (WG); Whey protein (WPC); Modified sweetpotato flour (MSPF); Defatted soy flour (DSF))

Composition[1]	SPF	TF	WG[3]	WPC[4]	MSPF	DSF[5]
Moisture content (%)	4.6	11.7	7.0	4.2	7.6	8.5
Ash (%)	3.1 (3.2)[6]	0.7 (0.8)	4.7 (5.0)	4.3 (4.5)	2.8 (3.0)	6.5 (7.0)
Fat (%)	1.0 (1.0)	0.1 (0.1)	1.9 (2.0)	4.4 (4.6)	0.6 (0.6)	1.4 (1.5)
Protein (%)	5.4 (5.7)	0.1 (0.1)	84.1 (90.0)	79.7 (83.0)	1.4 (1.5)	47.9 (52.0)
Carbohydrate[2] (%)	85.9 (90.1)	87.4 (99.1)	2.3 (3.0)	7.4 (7.9)	87.6 (95.0)	35.7 (39.5)
Fiber (%)	3.5 (3.7)	—	—	—	6.1 (6.6)	3.7 (4.0)

[1] Percentage based on wet weight basis.

[2] Carbohydrate includes contribution from fiber.

[3] Product specification obtained from Midwest Grain Products, Inc., Atchison, Kansas

[4] Product specification obtained from New Zealand Milk Products (North America), Inc., Santa Rosa, California

[5] Product specification obtained from Central Soya Company, Fort Wayne, IN

[6] Numbers in the parenthesis are composition based on dry weight.

Table 3.3. Color values of ingredients used in pasta formulation

Color values	SPF	TF	WG	WPC	MSPF	DSF
Lightness (L*)	85.7	94.6	89.4	88.5	84.6	93.9
Redness (a*)	12.7	0.4	-0.8	-1.7	11.2	-1.6
Yellowness (b*)	27.6	7.9	14.2	20.1	23.4	12.7
Hue angle	65.4	87.0	93.3	94.8	64.4	97.0
Chroma	30.39	7.9	14.2	20.2	25.9	12.8

SPF : Sweetpotato flour

TF : Tapioca flour

WG : Wheat gluten

WPC : Whey protein concentrate

MSPF : Modified sweetpotato flour

DSF: Defatted soy flour

Table 3.4. Cooking loss, firmness and color values of cooked pasta made from SPF as affected by added wheat gluten (WG) or whey protein concentrate (WPC) and tapioca flour (TF)

Treatments		Cooking loss (%)	Firmness (N)	Color Value				
				L*	a*	b*	Hue angle	Chroma
10%WG	0% TF	14.8	330.6	57.2	11.1	44.7	76.1	46.1
		(0.5)	(20.5)	(1.2)	(0.2)	(1.3)	(0.3)	(1.3)
	10% TF	13.7	369.9	58. 0	10.2	45.4	77.3	46.6
		(0.2)	(16.5)	(0.3)	(1.7)	(0.7)	(2.0)	(0.8)
	20% TF	12.3	408.2	58.4	9.6	46.1	78.3	47.1
		(0.4)	(22.5)	(0.9)	(1.9)	(0.5)	(2.2)	(0.8)
	30% TF	11.0	427.0	59.9	8.8	46.8	79.5	47.6
		(0.5)	(12.4)	(1.5)	(1.5)	(2.5)	(1.3)	(2.7)
10%WPC	0% TF	13.8	455.5	61.6	12.5	48.5	75.5	50.1
		(0.7)	(36.9)	(1.1)	(1.4)	(1.9)	(2.0)	(1.5)
	10% TF	11.9	490.7	62.9	12.2	49.1	75.9	50.6
		(0.7)	(60.4)	(1.7)	(1.5)	(3.1)	(2.5)	(2.7)
	20% TF	10.8	504.1	63.1	11.8	50.0	76.7	51.4
		(0.3)	(71.6)	(1.4)	(1.4)	(2.7)	(2.3)	(2.3)
	30% TF	9.9	576.4	64.1	11.0	50.4	77.7	51.6
		(0.5)	(42.2)	(3.1)	(1.0)	(2.5)	(1.3)	(2.5)

Numbers in parenthesis are standard deviation.

Table 3.5. Treatment effects on cooking characteristics of cooked pasta made by using extrusion method

	Cooking loss (%)	Firmness (N)	L*	a*	b*	Hue angle	Chroma
Level of TF[1]	**	*	ns	*	ns	**	ns
0% TF	14.3[a]	393.1[c]	59.4	11.8 [a]	46.6	75.8[c]	48.1
10% TF	12.8[b]	430.3[bc]	60.4	11.2 [a]	47.2	76.6[bc]	48.6
20% TF	11.6[c]	456.2[ab]	60.8	10.7 [ab]	48.1	77.5[b]	49.3
30% TF	10.5[d]	501.7[a]	62.0	9.9 [b]	48.6	78.6[a]	49.6
LSD	0.8	52.8	2.1	1.2	1.9	1.1	2.1
Protein[1]	**	**	*	ns	ns	ns	*
10% WG	13.0[a]	383.9[b]	58.4[b]	9.9	45.7	77.8	46.8[b]
10% WPC	11.6[b]	506.7[a]	62.9[a]	11.9	49.5	76.5	50.9[a]
LSD	0.4	63.7	2.4	2.8	3.8	3.9	3.3
Interaction	ns	ns	ns	ns	ns	ns	ns

* $p<0.05$; ** $p<0.01$; ns = no significant difference.

[1] TF= Tapioca flour; WG=Wheat gluten; WPC=Whey protein concentrate.

[a-d] Means with the same letter in the same column within a treatment indicate no significant difference ($p<0.05$).

Table 3.6. Color values of cooked pasta made from MSPF as affected by level of SPF and DSF substitution

Treatments		L*	a*	b*	Hue angle	Chroma
0% SPF	0% DSF	48.7	23.4	38.9	58.9	45.4
		(2.4)	(1.2)	(2.2)	(0.6)	(2.5)
	15% DSF	52.9	21.9	41.2	62.1	46.6
		(2.3)	(2.4)	(2.5)	(1.2)	(3.4)
	30% DSF	56.9	19.2	41.1	65.0	45.4
		(1.0)	(1.1)	(1.0)	(0.9)	(1.3)
15% SPF	0% DSF	50.6	22.8	39.6	60.2	45.7
		(2.0)	(0.6)	(0.7)	(0.4)	(0.8)
	15% DSF	53.1	21.1	40.1	62.3	45.3
		(2.8)	(1.2)	(1.2)	(0.9)	(1.6)
	30% DSF	55.4	18.6	39.5	64.7	43.6
		(2.4)	(0.7)	(1.6)	(1.6)	(1.3)
30% SPF	0% DSF	53.3	22.6	39.7	60.3	45.7
		(1.6)	(0.2)	(1.1)	(0.8)	(1.0)
	15% DSF	54.7	21.3	40.5	62.2	45.8
		(1.3)	(1.0)	(0.3)	(1.0)	(0.7)
	30% DSF	57.3	19.1	41.9	65.5	46.1
		(0.6)	(0.8)	(0.1)	(1.0)	(0.3)

Numbers in parenthesis are standard deviation.

Table 3.7. Treatment effects on color of cooked pasta made by using steaming method

	L*	a*	b*	Hue angle	Chroma
Levels of SPF[1]	*	ns	ns	ns	ns
0% SPF	52.8 [b]	21.5	40.4	62.0	45.5
15% SPF	53.0 [b]	21.0	39.7	62.4	44.8
30% SPF	55.1 [a]	20.8	40.7	62.7	45.8
LSD	1.9	1.2	1.4	1.0	1.4
Levels of DSF[1]	**	**	ns	**	ns
0% DSF	50.6 [a]	22.9 [a]	39.4	59.8 [a]	45.6
15% DSF	53.6 [b]	21.4 [b]	40.6	62.2 [b]	45.6
30% DSF	56.5 [c]	19.0 [c]	40.8	65.1 [c]	45.0
LSD	1.9	1.2	1.4	1.0	1.4
Interaction	ns	ns	ns	ns	ns

*$p<0.05$; **$p<0.01$;ns = no significant difference.

[1]SPF= Sweetpotato flour; DSF= Defatted soy flour.

[a-c]Means with the same letter in the same column within a treatment indicate no significant difference ($p<0.05$).

Table 3.8. Cooking loss, cooking yield and texture characteristics of cooked pasta made from MSPF as affected by level of SPF and DSF substitution

Treatments		Cooking loss (%)	Cooking yield (%)	Firmness (N)	Stickiness (Ns)	Cohesiveness	Springiness (mm)
0% SPF	0% DSF	5.6	335.7	1.9	3.6	0.67	0.85
		(1.5)	(11.0)	(0.1)	(0.3)	(0.08)	(0.08)
	15% DSF	6.7	346.8	1.3	2.7	0.67	0.84
		(0.4)	(11.1)	(0.1)	(0.7)	(0.00)	(0.01)
	30% DSF	8.5	344.2	1.2	2.8	0.64	0.79
		(0.2)	(9.0)	(0.3)	(0.8)	(0.02)	(0.08)
15% SPF	0% DSF	13.4	329.7	1.4	3.2	0.66	0.83
		(1.5)	(6.1)	(0.2)	(1.0)	(0.04)	(0.03)
	15% DSF	15.5	315.2	1.3	3.2	0.61	0.74
		(3.0)	(5.6)	(0.1)	(0.1)	(0.07)	(0.09)
	30% DSF	15.4	305.3	1.2	3.4	0.59	0.74
		(2.7)	(12.1)	(0.2)	(0.8)	(0.02)	(0.06)
30% SPF	0% DSF	20.2	319.2	1.4	3.9	0.60	0.72
		(3.8)	(6.7)	(0.3)	(0.1)	(0.06)	(0.04)
	15% DSF	22.8	305.0	0.9	3.6	0.53	0.69
		(5.7)	(9.2)	(0.4)	(0.9)	(0.06)	(0.07)
	30% DSF	18.4	305.4	1.0	3.6	0.55	0.71
		(0.8)	(7.4)	(0.1)	(0.4)	(0.05)	(0.02)

Numbers in parenthesis are standard deviation.

Table 3.9. Treatment effects on cooking characteristics of cooked pasta made by using steaming method

	Cooking loss (%)	Cooking yield (%)	Firmness (N)	Stickiness (Ns)	Cohesiveness	Springiness (mm)
Levels of SPF [1]	**	**	**	ns	**	**
0% SPF	6.9 [c]	342.2 [a]	1.5 [a]	3.0	0.66 [a]	0.83 [a]
15% SPF	15.4 [b]	316.7 [b]	1.3 [a]	3.2	0.62 [a]	0.77 [a]
30% SPF	20.5 [a]	309.9 [c]	1.1 [b]	3.7	0.56 [b]	0.71 [b]
LSD	2.7	8.9	0.2	0.7	0.05	0.06
Levels of DSF[1]	ns	ns	**	ns	ns	ns
0% DSF	13.1	328.2	1.5 [a]	3.6	0.64	0.80
15% DSF	14.8	322.3	1.2 [b]	3.3	0.61	0.75
30% DSF	15.0	318.3	1.1 [b]	3.2	0.59	0.75
LSD	2.7	8.9	0.2	0.7	0.05	0.06
Interaction	ns	*	ns	ns	ns	ns

*$p<0.05$; **$p<0.01$; ns = no significant difference.

[1]SPF= Sweetpotato flour; DSF= Defatted soy flour.

[a-c]Means with the same letter in the same column within a treatment indicate no significant difference ($p<0.05$).

Table 3.10. Cooking characteristics of different types of pasta

Cooking characteristics	Wheat noodle	Rice noodle	Experimental pasta 1[1]	Experimental pasta 2[2]
Color values "L*"	75.4	74.7	64.1	48.7
"a*"	2.2	-2.1	11.0	23.4
"b*"	13.3	2.1	50.4	38.9
Hue angle	80.6	136.3	77.7	59.0
Chroma	13.5	3.0	51.6	45.4
Cooking time (min)	7.0	4.0	2.0	4.0
Cooking loss (%)	3.4	2.6	9.9	5.6
Cooking yield (%)	231.1	271.2	223.6	335.7
Firmness (N)	9.5[3]	2.3[4]	7.7[3]	1.9[4]

[1] Pasta added 30% tapioca and fortified with 10% whey protein concentrate.

[2] Pasta made from 100% modified sweetpotato flour.

[3] Based on 1 gm of sample

[4] Based on 3 strands of noodle

Table 3.11. Correlation coefficients among quality characteristics of cooked sweetpotato Pasta made from steaming method

	Cooking loss	Cooking yield	Firmness	Stickiness	Cohesiveness
Cooking yield	-0.78**				
Firmness	-0.68**	0.35			
Stickiness	0.38	-0.42*	-0.03		
Cohesiveness	-0.76**	0.69**	0.66**	-0.29	
Springiness	-0.65	-0.65*	0.45*	-0.39*	0.77**

CHAPTER 4

EFFECT OF CHEMICAL MODIFICATION ON PASTING PROPERTIES OF SWEETPOTATO FLOUR AND SWEETPOTATO STARCH FOR PRODUCTION OF PASTA[1]

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ABSTRACT

Pasting characteristics of both sweetpotato flour and sweetpotato starch treated with or without sodium hypochlorite solution under alkaline condition were investigated using Brabender viscoamylograph. Sweetpotato flour (SPF) modified with sodium hypochlorite had higher pasting curve. Treatment without sodium hypochlorite under alkaline condition had only slight effect on pasting properties of sweetpotato starch. The viscosity of flour with the treatment of hypochlorite solution increased whereas the viscosity of commercial starch with the same treatment decreased. Chemical treatment significantly reduced the β-carotene contents of MSPF (23.80 mg/100g) and ASPF (27.26 mg/100g) as compared to that of control sample, the SPF (36.28 mg/100g). No significant difference among cooking characteristics of pasta made from MSPF and ASPF was observed.

INTRODUCTION

Sweetpotato roots are a good source of carbohydrates, carotenoids, dietary fibers, and minerals. Starch is the major component (50-70% dry matter) in sweetpotato (Woolfe, 1992). Starch pasting properties plays an important role in non-wheat pasta, which contains no gluten. Sweetpotato starch has been used for making starch noodles, which are popular in Asian countries such as China, Japan, Korea and Taiwan (Hong, 1982; Kim and Wiesenborn, 1996; Collado, 1997). However, many essential nutrients in sweetpotato especially β-carotene, fiber, and minerals are lost during the starch production process. Sweetpotato flour should be a good alternative for making nutritious pasta, but the pasting properties of sweetpotato flour is poor. Therefore, using modification method may help to improve pasting properties of sweetpotato flour.

Chemical modification has been used to change the functionality of starches. The reactions for modification include oxidation, hydrolysis, esterification, etherification, and dextrinization (Wurzburg, 1995; Thomas and Atwell, 1999). The functionalities or properties of modified starches are different depending on the process of manufacture. Crosslinked starches function as binder, viscosifier, and texturizer. Oxidized starches function as binder, film-former, and texturizer (Thomas and Atwell, 1999). Research has been conducted to produce starch noodles with crosslinked potato, sweetpotato, and tapioca starches (Chiu and Chua, 1989; 1990; Kasemsuwan et al., 1998; Muhammad et al., 1999); however, no literature on modification of sweetpotato flour for production of pasta and noodle is available. The objectives of this study were to modify sweetpotato flour and starch by using oxidation method and to analyze their pasting properties. The cooking qualities of pasta made from modified sweetpotato flour with and without oxidizing agent were also investigated.

MATERIALS & METHODS

Preparation of sweetpotato flour

Sweetpotato roots of deep orange color and jumbo size of Beauregard cultivar were purchased from Leeland Farm, Leesberg, GA. The roots were washed, hand-peeled, and sliced to a 2-mm thickness. Slices were soaked in 0.1% sodium metabisulfite before drying at 70 °C for 12 hrs. The dried sweetpotato chips were ground by using a Super Masscolloider (Masuko Sangyo Co., Ltd. Japan) and sifting by using Sweco Seperator (Sweco, Inc., Ft. Smith, Ark, USA) to pass through 80 mesh sieve. The flour was then vacuum-packaged in cryovac bags and stored at -18 °°C until used.

Commercial sweetpotato starch

Commercial sweetpotato starch (Imperial Taste, Tri-Pacific International, Ltd, Tainan, Taiwan) was purchased in a local market.

Modification of sweetpotato flour and starch

Sweetpotato flour and commercial sweetpotato starch was treated by using the method modified from Forssell et al. (1995). Sweetpotato flour and starch was suspended as a 20% (db) suspension and the pH of suspension was adjusted to 10.5 with 2 M NaOH solution. Sodium hypochlorite solution (4% NaOCl. Activity 1000 ppm Cl/Kg flour) was added to the stirred slurry for a reaction time of 3 hrs. The pH of suspension was then adjusted to 7.0 with 1 M Sulfuric acid, and 0.1% sodium bisulfite was added to destroy the excess chlorine. The suspension was then vacuum filtered, washed twice with distilled water and dried at 50 °C overnight. Three replicates were done for each treatment.

Sweetpotato flour and starch were also treated with the method described above without adding sodium hypochlorite (oxidizing agent) and sodium bisulfite (reducing agent) under alkaline condition. The products were called alkaline-treated sweetpotato flour (ASPF) and alkaline-treated commercial sweetpotato starch (ACSPS).

Pasting characteristics

Pasting profiles of sweetpotato flour and starch were determined by using a Brabender Visco-amylograph (Type PT-100/VA-VE, C.W. Brabender Instruments, Inc., NJ, USA) equipped with 700 cm.gf cartridge. A suspension of 7% (dry weight/v) sample was heated from 30 to 95 °C at a rate of 1.5 °C/min with constant stirring at 75 rpm. The sample was held at 95 °C for 30 min (breakdown), then cooled to 50 °C at a rate of 1.5 °C/min (setback), and then held for 30 min. Pasting temperature (PT) was defined as the temperature at which an increase in viscosity was first observed. Peak viscosity (PV) was defined as the point at which, during heating in water, gelatinized starch reaches its maximum viscosity. Viscosity at 95 °C (V 95°C) was the viscosity when the paste reached a temperature of 95 °C. Viscosity at 95 °C hold (V 95°C H) was the viscosity after cooking the paste at 95 °C for 30 min in the amylograph. Viscosity at 50 °C

(V 50°C) was the viscosity when the paste was cooled down to 50 °C. Viscosity at 50 °C hold (V 50°C H) was the viscosity after cooling the paste at 50 °C for 30 min in the amylograph. Hot-paste stability (HPS) was defined as the ratio of viscosity at breakdown to viscosity at 95 °C. Retrogradation tendency (RT) was defined as the ratio of viscosity at setback to viscosity at breakdown. Cool-paste stability (CPS) was defined as the ratio of viscosity at 50 °C held for 30 min to viscosity at setback. The viscosity was reported in term of Brabender unit (BU).

Proximate composition

Proximate composition of samples was determined by AOAC (1997) methods as follows: moisture by the vacuum oven method 925.09; ash by the muffle furnace method 923.03; crude protein by Kjeldahl method 960.52 (using 6.25 as conversion factor); crude fat by petroleum ether extraction method 920.85; and carbohydrate by substracting percentage of other solids (ash+ fat+protein) from 100%. Crude fiber was determined by method 962.09.

β-carotene analysis of sweetpotato flour

The method of β-carotene analysis was followed by the method of Zhang (1998) with slightly modification. Three grams of dried ground sample were extracted with isopropanol and hexane three times in the ratio of 5:15, 3:15, and 3:15 ml by using homogenizing (Omni Mixer Homogenizer, Waterbury, CT) for 2, 1, and 1 min, respectively. One gram of magnesium sulfate was added to the mixture during the first homogenization to remove water. Each extract was vacuum filtered, and the filtrate was brought to volume with hexane containing 0.1% BHT (w/v) in a 100 ml volumetric flask. One milliliter of each extract was evaporated to dryness under a stream of N_2, and redissolved in 2 ml of mobile phase, acetonitrile/methanol/tetrahydrofuran (25/28/2, v/v/v).

All-trans-β-carotene was quantified by high performance liquid chromatography (HPLC). A system comprised of a C_{18}218TP54 Vydac column (5 μm, 4.6 mm x 25 cm) (vydac, Hesperia, CA), a Thermoseperation pump (Thermo Finnigan, San Jose, CA), and Isco V^4 Absorbance dector (Isco, Inc., Lincoln, NA) set at 450 nm as a detector. The flow rate of mobile phase was adjusted to 1 ml/min. The peak area was determined by using Hewlett Packard integrator Model HP 3395 (Hewlett-Packard, Co., Wilmington, DE).

Stock solution of β-carotene was prepared by weighing 5 mg of trans-β-carotene (Fluka Bio Chemika, St. Louis, MO) into 25 ml volumetric flask and making volume with hexane. Determine absorbance difference at 453 nm and calculate the concentration of stock solution from coefficient of β-carotene ($E^{1\%}_{1cm}$ =2592) (Bauernfeind, 1981). Six concentrations of standard solution (0.5-4.0 μg/ml) were used to determine standard curve.

Preparation of pasta

MSPF and ASPF were selected to produce pasta in order to keep the nutrient of sweetpotato. Flour was prepared as a 20% (db) suspension. The slurry (50 gm) was put in an 8” diameter pan and steam-cooked by using steamer with boiling water for 4 min. The pasta sheet was removed from the pan, cut into 0.6 mm width by using noodle maker machine (Atlas®, model 150, Italy), and dried at 50 °C for 4 hrs.

Cooking characteristics of pasta

Cooking loss was measured by a modification of AACC Method (1995). Samples (5 gm) were cooked in 200 ml boiling distilled water for 4 min, rinsed with 50 ml distilled water and drained for 5 min. The cooking and rinse water was collected and dried in an air oven at 100 °C. Remaining solids were weighed to determine cooking loss, which was expressed as percentage of initial dry matter.

The color of cooked pasta was measured using a hand-held Minolta Chroma meter (Model CR-200, Minolta Corporation, Japan). Sample was placed in the sample cup for measurement. Color values were recorded as “L*” (lightness), “a*” (redness), and “b*” (yellowness). From a* and b* values, the hue angle ($\tan^{-1}$ b*/a*) and chroma ($((a^{*2}+b^{*2})^{1/2})$) were calculated.

The pasta firmness test was modified from AACC method (1995). The firmness of cooked pasta was measured using an Instron Universal Testing Machine Model 1122 (Instron Corporation, Canton, MA) equipped with a 50 N load cell and a cutting plexiglass blade. Three strands of cooked pasta were placed on a sample holder parallel to each other. Testing parameters for analysis were set at 5mm/min crosshead speed. The maximum forces required to shear the sample were recorded. All trials were done in triplicates.

A texture profile analysis (TPA) of pasta was conducted to determine adhesiveness (stickiness), cohesiveness and springiness of cooked pasta by using method of Voisey et al. (1978) and Tang et al. (1999) with modification. Three strands of pasta were placed on a sample holder, which had a 90 degree grooves surface, and compress to

75% of the depth of pasta with a flattened cylinder aluminum plunger (5.5 cm diameter) using 5 mm/min crosshead speed.

Statistical Analysis

General Linear Models (GLM) procedure was used to analyze the data of pasta quality means from each treatment. Where significant differences were found, means ere separated using Duncan's multiple range test (SAS Institute, 1989).

RESULTS & DISCUSSION

Pasting characteristics

Pasting curve patterns of sweetpotato flour and starch with or without modification were shown in Fig. 4.1. Modified sweeptpotato flour (MSPF) and Alkaline treated sweetpotato flour (ASPF) exhibited C-type (restricted swelling) (Fig. 4.1a) as classified by Schoch and Maywald (1968); however no pasting curve of sweetpotato flour (SPF) was observed at the same concentration (7% w/v) indicated that no gelatinization of starch occurred. Although the starch content of SPF was 51.9%, other constituents such as sugar and fiber could affect the pasting properties. Those two components, accounted for 38.3% (dwt) in SPF, could compete with starch molecules in absorption of water and inhibit the gelatinization of starch. However, the pasting curve of SPF suspension at 15% (w/v) showed a very low viscosity. The paste viscosity increased during cooling period. This could be the effect of fiber as reported by Kohyama and

Nishinari (1992) that cellulose derivatives (i.e. carboxylmethy cellulose and microcrystalline cellulose), which were water-insoluble, increased starch retrogradation.

Commercial sweetpotato starch (CSPS) and Alkaline treated commercial sweetpotato starch (ACSPS) exhibited A-type (high swelling), which was similar to those of tuber starches, whereas modified commercial sweetpotato starch (MCSPS) showed the lower pasting curve (Fig. 4.1b). The viscosity of MCSPS was significantly decreased. The chemistry of hypochlorite oxidation primarily involved carbon 2, 3 and 6 on a D-glucopyranosyl unit. Generally, about 25% of oxidizing reagent was consumed in carbon-carbon splitting while about 75% oxidized hydroxyl groups (Thomas and Atwell, 1999). The decrease in viscosity was caused by partial cleavage of the glucosidic linkages from extensive oxidation, resulting in a decrease in molecular weight of starch molecules (Morton and Solarek, 1984). This partially degraded network was not resistant to shear and could not maintain the integrety of starch granule and thereby produce a lower viscosity (Kuakpetoon and Wang, 2001). In contrast, the viscosity of MSPF was increased ($p<0.05$) due to NaOCl would first oxidize protein before attacking hydroxyl groups on starch molecules in an oxidation reaction. Therefore, there will be less residual NaOCl to oxidize starch if a starch sample has a higher protein content (Kuakpetoon and Wang, 2001). In this study, the protein content of SPF (5.67%) was higher than that of CSPS (0.03 %) (Table 4.2). Thus, there was less NaOCl to react with starch molecules. Protein may not be the only factor affecting the viscosity of MSPF. Other component such as fiber could affect the paste viscosity. The fiber content of SPF (3.72%) was higher than that of CSPS (0.08%). Since fiber consists of several polysaccharides, it may greatly affect the physical properties of sweetpotato starch (Kohyama and Nishinari, 1992). Besides, the water-binding capacity of the cellulose increased when the nonwoody portions of plant fruits, roots, and tubers, were treated with the oxidizing agent under alkaline solution as report by Gould (1989).

The pasting temperature of sweetpotato flour ranged from 69.9 to 70.5 °C, whereas the pasting temperature of commercial sweetpotato starch with and without treatment ranged from 61.3 to 62.7 °C (Table 4.1). This may be due to different variety of sweetpotato. Walter et al. (2000) reported that the gelatinization temperature of sweetpotato starch (Beauregard cultivar) was 71.4 °C, which is similar to that of modified sweetpotato flour (70.5 °C).

The differences between peak viscosity and viscosity at 95 °C of MSPF and ASPF were relatively small (Table 4.1), indicating the ease of cooking of flour. The broad pasting peaks of MCSPS showed low shear-thinning behavior or good hot-paste stability. The pasting viscosity of flour and starch decreased during heating period (95 °C, 30 min) (Table 4.1), indicating the breakdown of starch molecules during the cooking process.

The differences between viscosity at 50 °C and 50 °C hold of all samples were small (Table 4.1), indicating good cool paste stability. However, the viscosity of CSPS, MCSPS and ACSPS during the cooling period (50 °C, 30 min) increased whereas those of MSPF and ASPF slightly decreased. The retrogradation tendency of modified sweetpotato flour and starch were significantly higher than those of alkaline treated flour and starch, indicating the higher rate of recrystallization of modification flour and starch.

β-carotene analysis

The β-carotene content of SPF was 36.3 mg/ 100g dry weight, which was equivalent to 3,023 retinol activity equivalent (RAE). After the chemical treatment, the β-carotene contents of MSPF (23.8 mg/100g) and ASPF (27.3 mg/100g) were significantly lower as compared to that of SPF (Table 4.3). However, the amount of β-carotene in both flour were still high as compared to DRI for adult men (900 RAE) (DRI, 2001). The RAE of MSPF and ASPF was 1,984 and 2,362, respectively. This result indicated that MSPF and ASPF were a good source of β-carotene.

Cooking characteristics of pasta

MSPF and ASPF were used to produce pasta in order to keep the nutrients of sweetpotato. Cooking characteristics of pasta made from MSPF and ASPF were shown in Table 4.4. No significant difference among cooking characteristics of pasta made from MSPF and ASPF was observed.

CONCLUSION

Modification of sweetpotato flour with sodium hypochlorite and sodium hydroxide significantly improved the pasting properties of sweetpotato flour. Sweetpotato starch could be used as an ingredient to produce starch noodles; however, using modified sweetpotato flour would have more benefit to keep some essential nutrients such as β-carotene, fiber, and minerals. Thus, MSPF and ASPF could be the alternative ingredients for production of pasta with nutritious nutrients and yellow-orange natural color.

ACKNOWLEDGMENTS

We thank Dr. Klanarong Sriroth, Head of Cassava and Starch Technology Research Unit, National Center for Genetic Engineering and Biotechnology, Bangkok, Thailand, for his advice in modification method of flour. We acknowledge Dr. Ronald R. Eitenmiller and Dr. Lin Ye for technical advice in HPLC analysis of β-carotene. We also thank Kay H. McWatters and Dr.Yvonne Mensa-Wilmot for assistance in Brabender viscoamylograph.

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Table 3.1. Pasting characteristics of sweetpotato flour and starch as affected by modification methods

Treatment[1]	PT (°C)	PV (BU)	V95°C (BU)	V95°C H (BU)	V50°C (BU)	V50°C H (BU)	HPS	CPS	RT
SPF*	—**	—	20.0 e	20.0 e	55.0 e	55.0 d	—	—	—
MSPF	70.5 a	697.5 b	691.3 a	505.8 a	760.0 a	716.3 a	0.73 b	0.95 b	1.10 b
ASPF	69.9 a	605.0 b	570.0 b	440.0 b	610.0 b	580.0 b	0.77 a	0.95 b	1.07 b
CSPS	61.5 b	1085.0 a	455.0 c	305.0 c	505.0 c	550.0 b	0.67 c	1.10 a	1.11 b
MCSPS	62.7 b	445.0 c	285.0 d	220.0 d	395.0 d	425.0 c	0.78 a	1.08 a	1.39 a
ACSPS	61.3 b	1175.0 a	470.0 c	287.5 c	425.0 cd	522.5 b	0.62 d	1.13 a	0.99 b

[1]SPF=Sweetpotato flour; MSPF= Modified sweetpotato flour; ASPF= Alkaline-treated sweetpotato flour; CSPS= Commercial sweetpotato starch; MCSPS= Modified commercial sweetpotato starch; ACSPS= Alkaline-treated commercial sweetpotato starch.

[a-e] Different letters in each column indicate significant differences at $p<0.05$.

* 15% (w/v) concentration.

** Not determined because there was insignificant gelatinization and retrogradation.

Table 4.2. Proximate composition of sweetpotato flour (SPF) and commercial sweetpotato starch (CSPS)

Composition[1]	SPF	CSPS
Moisture content (%)	4.58	12.40
Ash (%)	3.09 (3.24)[3]	0.24 (0.27)
Fat (%)	0.92 (0.96)	0.04 (0.05)
Protein (%)	5.42 (5.67)	0.03 (0.03)
Carbohydrate[2] (%)	85.99 (90.13)	87.29 (99.65)
Fiber (%)	3.56 (3.72)	0.07 (0.08)

[1] Percentage based on wet weight basis.

[2] Carbohydrate includes contribution from fiber.

[3] Numbers in the parenthesis are composition based on dry weight.

Table 4.3. β-carotene content of native and modified sweetpotato flour

Treatment[1]	β-carotene (mg/100 g dry weight)	Retinol activity equivalent[2]
SPF	36.28 a	3,024 a
MSPF	23.80 b	1,984 b
ASPF	27.26 b	2,362 b

[1]SPF= Sweetpotato flour; MSPF= Modified sweetpotato flour; ASPF= Alkaline-treated sweetpotato flour.

[2]Retinol activity equivalent (RAE): 1 μg RAE = 1 μg retinol = 12 μg β-carotene

Table 4.4. Cooking characteristics of sweetpotato pasta made from modified sweetpotato flour (MSPF) and alkaline-treated sweetpotato flour (ASPF)

Treatment	MSPF^{ns}	ASPF^{ns}
Cooking loss (%)	5.1 ± 0.8	5.2 ± 1.2
Cooking yield (%)	336.4 ± 11.0	357.0 ± 20.6
Color "L*"	47.9 ± 1.2	47.6± 1.0
"a*"	22.2 ± 1.7	23.0 ± 1.0
"b*"	37.1 ± 1.5	35.5 ± 0.4
Hue angle	59.1 ± 1.0	57.1 ± 1.0
Chroma	43.3 ± 2.1	42.3 ± 0.7
Firmness (N)	1.8 ± 0.0	1.4 ± 0.2
Stickiness (Ns)	3.3 ± 0.5	2.9 ± 0.6
Cohesiveness	0.7 ± 0.1	0.7 ± 0.0
Springiness (mm)	0.8 ± 0.1	0.8 ± 0.0

^{ns} There is no significant difference.

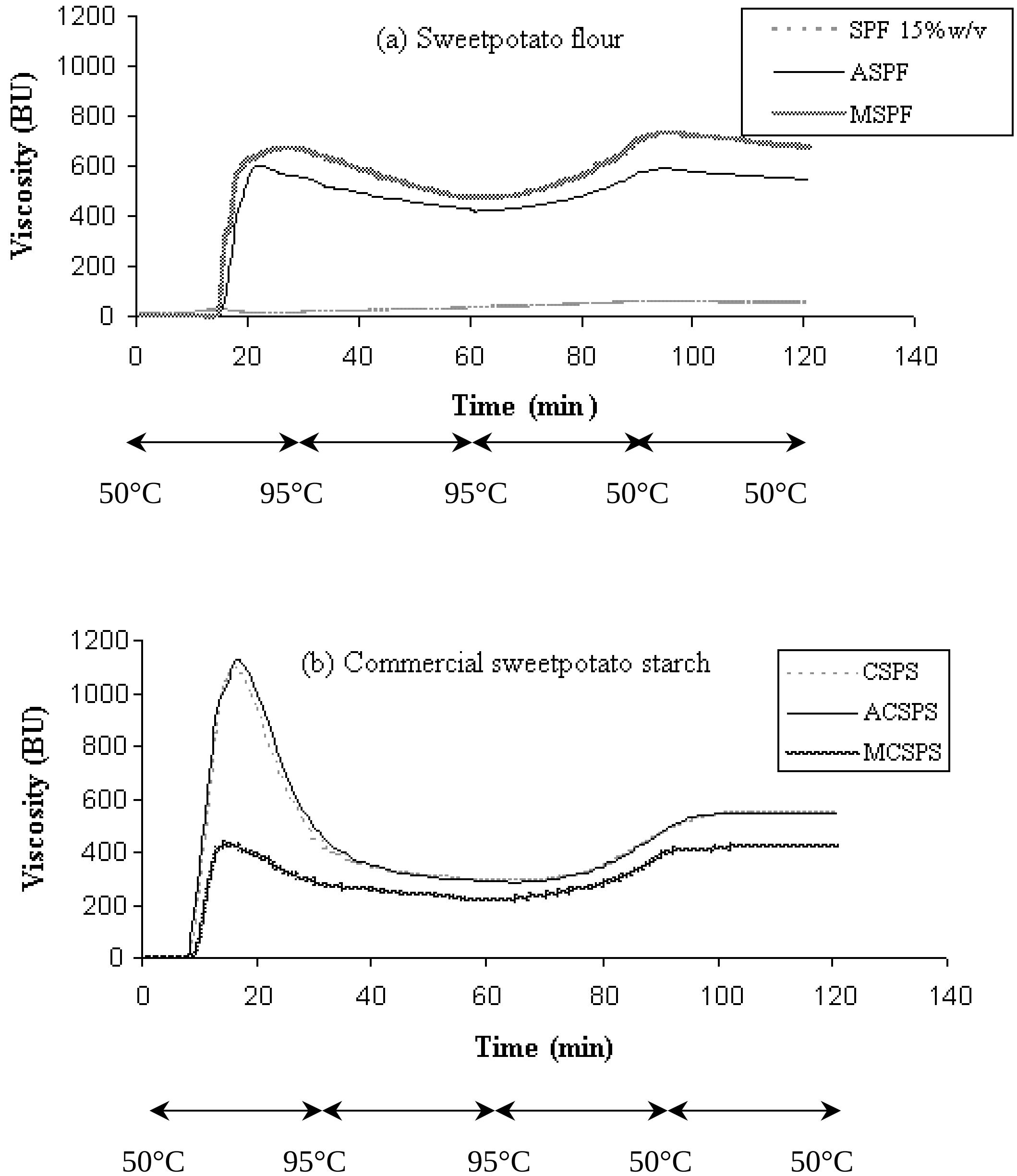

Fig. 4.1. Brabender viscoamylograph of native and modified sweetpotato flour and starch

CHAPTER 5

DEVELOPMENT OF PASTA PRODUCTS USING ALKALINE-TREATED SWEETPOTATO FLOUR AND FORTIFIED WITH SOY PROTEIN[1]

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ABSTRACT

Sweetpotato flour (Beauregard cultivar) was treated with sodium hydroxide solution and then fortified with defatted soy flour (DSF) or soy protein concentrate (SPC) at level of 0, 15, 30, and 45 %. Pasta made from 100% alkaline-treated sweetpotato flour (ASPF) had lowest cooking loss (9.9%) and the highest firmness (1.8 N). Cooking loss increased as levels of DSF and SPC increased (from 9.9 to 16.6%). Addition of DSF and SPC increased the lightness (“L*” value) from 40.6 to 48.7, and decreased the redness (“a*” value) from 21.6 to 15.2. Substitution of DSF and SPC decreased firmness from 1.8 to 0.4 N, cohesiveness from 0.6 to 0.5 and springiness from 1.2 mm to 1.1 mm. Pasta made from 100% ASPF had highest β-carotene content (9.0 mg/100 g). The β-carotene contents decreased from 7.9 to 2.7mg/100g as the levels of DSF and SPC increased.

INTRODUCTION

Sweetpotato is a great source of carbohydrates, β-carotene (provitamin A), and fiber. It is considered as a staple and co-staple in many countries in Asia and Africa. (Woolfe, 1992). Utilization of sweetpotato flour in pasta has been studied; however, sweetpotato was used as wheat-sweetpotato composite flour (Thirumaran and Ravindran, 1992; Collado and Corke, 1996; Collins and Pangloli, 1997). In wheat pasta, gluten protein contributes the desirable cooking qualities and texture of products (Feillet and Dexter, 1996). Since sweetpotato lacks of gluten protein, it is difficult to make the pasta from the whole sweetpotato by using wheat pasta manufacture method. The production of rice noodles, which are popular in Southeast Asian countries such as Thailand and Vietnam, can be made with the absence of gluten. In this type of products, the starch pasting properties play an important role to the product qualities (Miskelly, 1993).

Chemical modification methods were applied to various types of starches to improve physicochemical properties of starches. Sodium hydroxide was used to isolate starch from Legume flour, oat flour, and cowpea flour (Schoch and Maywald, 1968; Lim et al., 1992; Prinyawiwatkul, el al., 1997). Sodium hydroxide can separate starch by dissolving protein without gelatinization of starch (Schoch and Maywald, 1968). Our previous study has shown that no significant difference was observed among the cooking characteristics of pasta made by batter process from sweetpotato flour treated with sodium hypochlorite and flour treated with sodium hydroxide. In this study sweetpotato flour treated with sodium hydroxide was used to produce pasta by extrusion process. Since the protein content in sweetpotato was low, protein sources such as soy flour and soy protein concentrate were added to enhance the nutritive quality of products. The objectives of this study were to develop new pasta from alkaline treated sweetpotato flour fortified with soy proteins and to examine the quality of cooked product including cooking characteristics, protein and β-carotene content.

MATERIALS & METHODS

Materials

Sweetpotato flour was prepared from sweetpotato roots of deep orange color and jumbo size of Beauregard cultivar, which were purchased from Leeland Farm in Leesberg, GA. The roots were washed, hand-peeled, and sliced to 2 mm thickness. Slices were soaked in 0.1% sodium metabisulfite before drying at 70 °C for 12 h. The dried sweetpotato chips were ground by using a Super Masscolloider (Masuko Sangyo Co., Ltd. Japan) and sifting by using Sweco Seperator (Sweco, Inc., Ft. Smith, Ark, USA) to pass through 80 mesh sieve. The flour was then vacuum-packaged in cryovac bags and stored at -18 °C until used. Defatted soy flour (Soyafluff® 200W) and soy protein concentrate (Procon® 2000) were provided by Central Soya Company, Inc. (Fort Wayne, IN).

Preparation of alkaline treated sweetpotato flour

Sweetpotato flour prepared from above method was modified followed by the method of Forsell et al. (1995) with modification. The flour was suspended as a 20% (db) suspension and pH was adjusted to 10.5 with 2 M NaOH solution, stirred for 3 hrs, and neutralized with 1 M Sulfuric acid. The suspension was vacuum filtered, washed twice with distilled water, dried at 50 °C overnight, ground by Ultra Centrifugal Mill Model ZM 100 (F. Kurt Retsch GmbH & Co., Haan, Germany) to pass through 0.5 mm screen.

Preparation of pasta

Pasta samples were prepared from ASPF with a replacement of DSF and SPC at the levels of 0, 15, 30 and 45%. A Mixture of flour and water (50%) was mixed in a KitchenAid Mixer (Model KSM50PWH, St. Joseph, MI) for 10 min, and steam-cooked by using steamer with boiling water for 5 min. The dough was kneaded in the KitchenAid Mixer for 2 min in order to distribute the heat to gelatinize the dough, then extruded through 2 mm die by using noodle maker (China). The extruded pasta was dried at the ambient temperature until the moisture content was approximately 10%. Three replicates were done for each formulation.

Proximate composition of ingredients

Proximate composition of samples was determined by AOAC (1997) methods as follows: moisture by the vacuum oven method 925.09; ash by the muffle furnace method 923.03; crude protein by Kjeldahl method 960.52 (using 6.25 as conversion factor); crude fat by Petroleum ether extraction method 920.85; and carbohydrate by subtracting percentage of other solids (ash+ fat+protein) from 100%. Crude fiber was determined by method 962.09.

Color measurement

The color of ingredients and cooked pasta was measured using a hand-held Minolta Chroma meter (Model CR-200, Minolta Corporation, Japan). Sample was placed in the sample cup for measurement. Color values were recorded as "L*" (lightness), "a*" (redness), and "b*" (yellowness). From a* and b* values, the hue angle ($\tan^{-1}$ b*/a*) and chroma ($(a^{*2}+b^{*2})^{1/2}$) were calculated.

Cooking quality of pasta

Cooking loss was measured by a modification of AACC Method (1995). Samples (5 gm) were cooked in 200 ml boiling distilled water for 5 min, rinsed with 50 ml distilled water and drained for 5 min. The cooking and rinse water was collected and dried in an air oven at 100 °C. Remaining solids were weighted to determine cooking loss, which was expressed as percentage of initial dry matter.

Texture analysis of cooked pasta

Pasta firmness test was modified from AACC method (1995). The firmness of cooked pasta was measured using an Instron Universal Testing Machine Model 1122 (Instron Corporation, Canton, MA) equipped with a 50 N load cell and a cutting plexiglass blade. Three strands of cooked pasta were placed on a sample holder parallel to each other. Testing parameters for analysis were set at 5 mm/min crosshead speed. The maximum forces required to shear the sample were recorded. All trials were done in triplicates. The average forces were calculated for one strand of pasta.

A texture profile analysis (TPA) of pasta was conducted to determine adhesiveness (stickiness), cohesiveness and springiness of cooked pasta by using method of Voisey et al. (1978) and Tang et al. (1999) with modification. One strand of pasta were placed on a sample holder, which had a 90 degree grooves surface, and compress to 75% of the depth of pasta with a flattened cylinder aluminum plunger (5.5 cm diameter) using 5 mm/min crosshead speed. On the force-time curve, adhesiveness was defined as the negative force area after the first compression, representing the work necessary to pull the compressing plunger away from the sample. Cohesiveness was defined as the ratio of the area under the second peak to the area under the first peak. Springiness was defined as the distance at which a deformed sample went back to its non-deformed condition after the deforming force is removed during the second compression.

β-carotene analysis

The method of β-carotene analysis was followed by the method of Zhang (1998) with a little modification. Three grams of dried ground sample were extracted with isopropanol and hexane three times in the ratio of 5:15, 3:15, and 3:15 ml by using homogenizing (Omni Mixer Homogenizer, Waterbury, CT) for 2, 1, and 1 min, respectively. One gram of magnesium sulfate was added to the mixture during the first homogenization to remove water. Each extract was vacuum filtered, and the filtrate was brought to volume with hexane containing 0.1% BHT (w/v) in a 100 ml volumetric flask. One milliliter of each extract was evaporated to dryness under a stream of N_2, and redissolved in 2 ml of mobile phase, acetonitrile/methanol/tetrahydrofuran (25/28/2, v/v/v).

All-trans-β-carotene was quantified by high performance liquid chromatography (HPLC). A system comprised of a C_{18}218TP54 Vydac column (5 µm, 4.6 mm x 25 cm) (vydac, Hesperia, CA), a Thermoseperation pump (Thermo Finnigan, San Jose, CA), and Isco V^4 Absorbance detector (Isco, Inc., Lincoln, NA) set at 450 nm. The flow rate of mobile phase was adjusted to 1 ml/min. The peak area was determined by using Hewlett Packard integrator Model HP 3395 (Hewlett Packard, Co., Wilmington, DE).

Stock solution of β-carotene was prepared by weighing 5 mg of trans-β-carotene (Fluka Bio Chemika, St. Louis, MO) into 25 ml volumetric flask and making volume with hexane. Determine absorbance difference at 453 nm and calculate the concentration of stock solution from coefficient of β-carotene ($E^{1\%}_{1cm}$ =2592) (Bauernfeind, 1981). A working standard solution was prepared by taking 1 ml of stock solution into 10 ml volumetric flask and making the volume with hexane.

Cooking characteristics of commercial pasta

The experimental pasta products obtained from the control pasta and pasta fortified with DSF and SPC were compared to the commercial pasta products. Commercial wheat noodle (Iron-Man®, Great Wall Enterprise Co., Ltd., Taipei, Taiwan) had the dimension of 0.6 mm width x 1.0 mm thickness while rice noodle (Asian Best®, Eastland Food Co., Bangkok, Thailand) had the dimension of 0.4 mm width x 1.2 thickness. Color, cooking loss, cooking yield and firmness of cooked pasta were measured using the method described above.

Statistical Analysis

General Linear Models (GLM) procedure was used to analyze the data of pasta quality means from each treatment. Where significant differences were found, means were separated using the least significant difference (SAS Institute, 1989).

RESULTS & DISCUSSION

Chemical composition of ingredients

Proximate composition of raw materials was shown in Table 5.1. ASPF was a significant source of carbohydrates (94.5%db). The protein content of DSF (52.0%db) and SPC (70.0 %db) was higher than ASPF (2.0%db). The ash content of ASPF, DSF and SPC were 2.8, 7.0, and 6.0% (db), respectively. All ingredients contained low fat content (0.8-1.5%db).

Color measurement

The color of dried flour was shown in Table 5.2. The a* value of ASPF was 12.1, which was higher than those of DSF (-1.6) and SPC (-0.6). The b* value of ASPF (23.0) was also higher than those of DSF (12.7) and (10.7). However, the L* value of ASPF (82.7) was lower than DSF (93.9) and SPC (92.7). The hue angle of ASPF was 62.2, indicating the orange color of flour while the hue angles of DSF and SPC were 97.0 and 93.3, respectively, indicated the cream color of soy proteins.

Fortification of DSF in pasta formulation significantly affected the color of cooked products. Addition of DSF and SPC (0, 15, 30, 45%) significantly increased L* and hue angle and decreased a* of cooked pasta; however, DSF and SPC did not affect b* and chroma (Table 5.3). The hue angles ranged 57.7-67.7 (Table 5.4) implied that pasta had an orange color. The yellow-orange color of sweetpotato flour was caused by the presence of carotenoid pigments, which affect the red-green chromaticity (Callado et al., 1997; Van Hal, 2000). Supplementation of DSF and SPC (cream color) tended to reduce the corotenoid pigments of ASPF.

Cooking quality of pasta

Pasta made from 100% ASPF had lowest cooking loss (9.9%), and lowest cooking yield (198.5%). Cooking loss of pasta significantly increased with the increasing level of DSF and SPC (Table 5.5). Cooking losses at 15, 30 and 45% were 11.2-15.8% and 11.5-16.6%, respectively. Cooking loss increased to 11.2-15.8% and 11.5-16.6% as the levels of DSF and SPC increased to 15-45%, respectively (Table 5.6). However, there was no significant difference of losses among the levels of DSF and SPC at 15% and 30%. Collins and Pangloli (1997) reported that addition of 10-15% sweetpotato and soy flour in wheat noodles increased cooking loss of products. Cooking yield significantly increased as the levels of soy proteins increased, but no significant difference of cooking yields among levels of DSF and SPC was observed. (Table 5.5). Cooking yields of pasta supplemented with DSF and SPC at 15, 30 and 45% were 200.4-208.5% and 202.0-212.8%, respectively (Table 5.6).

Texture of cooked pasta

Levels of soy protein significantly decreased firmnesss, stickiness, and springiness (Table 5.5). Firmness of sweetpotato pasta significantly decreased from 1.8 to

0.9 N (Table 5.6) as the levels of DSF and SPC increased. Pasta made from 100% ASPF had highest firmness (1.8 N). Addition of 15-45% of DSF and SPC decreased the firmness to 1.0-0.4 N and 1.1-0.4 N, respectively.

Stickiness of pasta signifiantly decreased as the levels of DSF and SPC increased. At 15% DSF and SPC substitution, stickiness of pasta was not significantly difference as compared to stickiness of pasta made from 100% ASPF (Table 5.5).

Cohesiveness of pasta tended to decrease from 0.59 to 0.57 (Table 5.6) as the level of DSF and SPC increased. No significant difference was observed among the cohesiveness of pasta in all treatment. Springiness of pasta significantly from 1.18 to 1.07 mm (Table 5.6); however, there was no significant difference among springiness of pasta made from pasta fortified with 15% and 30% DSF or SPC and 100% ASPF (Table 5.5).

Protein content and β-carotene content

Both types of soy proteins and levels of fortification significantly increased protein content of pasta (Table 5.7). Protein content of pasta fortified with 15%, 30%, and 45% DSF increased up to 4.6, 8.8, and 13.2 times, respectively, whereas protein content of pasta fortified with 15%, 30%, and 45% SPC increased up to 5.4, 10.4, and 15.9 times, respectively, as compared to pasta made from100% ASPF (1.9%). The ranges of protein content of dried pasta fortified with DSF and SPC at 15%, 30% and 45% were 8.9-25.5% (db) and 10.4-30.7% (db), respectively (Table 5.8).

The β-carotene content of pasta significantly decreased as the level of DSF and SPC increased (Table 5.7). Pasta made from 100% ASPF contained highest amount of β-carotene (751 RAE) (Table 5.8). At 15% substitution of DSF or SPC, sweetpotato pasta also contained high β-carotene content, 658 RAE and 646 RAE, respectively, which accounted for 71-73% for adult male and 92-94% for adult female as recommendation intake by DRI (900 RAE for adult male and 700 RE for adult female) (DRI, 2001). The β-carotene content decreased about 50–70 % as the levels of DSF and SPC increased to 30-45%. This may due to addition of soy proteins decreased carotenoid pigment of ASPF. In addition, lipoxygenase (enzyme in soybean) may cause the destruction of carotenes (Whitaker, 1996).

Correlation among cooking characteristics of sweetpotato pasta

Correlation among cooking quality characteristics were analyzed (Table 5.9). Cooking loss was negatively correlated with firmness ($r = -0.84$, $p<0.01$), stickiness ($r = -0.75$, $p<0.01$), and springiness ($r = -0.44$, $p<0.05$), but positively correlated with cooking yield ($r=0.49$, $p<0.05$). Thus, cooking loss increased as firmness, stickiness and springiness decreased. Kim and Wiesenborn (1996) reported that firmness of cooked potato starch noodles was negatively correlated to cooking loss ($r = -0.52$) and cooked weight ($r = -0.82$) at $p<0.01$, which was agreed to our correlation.

Firmness was negatively correlated with cooking loss ($r = -0.84$, $p<0.01$) and cooking yield ($r= -0.56$, $p<0.01$), but positively correlated with stickiness ($r = 0.76$, $p<0.01$). Stickiness was positively correlated with springiness ($r = 0.74$, $p<0.01$). Cohesiveness was positively correlated springiness ($r = 0.74$, $p<0.01$).

Cooking characteristics of commercial pasta

The color of commercial wheat and rice pasta were pale yellow and white color while our pasta products were in the range of orange color (57.6-61.9 hue angle) indicated that the carotenoid pigment still presented in our products. Both commercial wheat and rice pasta had lower cooking loss than our experimental pasta (Table 5.10). The firmness of our experimental pasta products was higher than that of rice noodle, but lower than that of wheat noodle. However, other factor such as thickness might affect the firmness of pasta.

CONCLUSION

Pasta made from 100% ASPF had the lowest cooking loss, the highest firmness and β-carotene content among samples. Pasta fortified with 15% DSF or 15% SPC contained approximately five times higher protein content as compared to pasta made from 100% ASPF. The products also contained β-carotene content higher than that of recommended by RDA. These products also had cooking quality, stickiness, cohesiveness, and springiness similar to pasta made from 100% ASPF.

ACKNOWLEDGMENTS

We thank Dr. Ronald R. Eitenmiller and Dr. Lin Ye for technical advice in HPLC analysis of β-carotene.

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Table 5.1. Proximate composition of ingredients

Composition[1]	ASPF	DSF[3]	SPC[3]
Moisture content (%)	8.0	8.5	10.0
Ash (%)	2.6 (2.8)[4]	6.5 (7.0)	5.5 (6.0)
Fat (%)	0.7 (0.8)	1.4 (1.5)	0.7 (0.8)
Protein (%)	1.9 (2.0)	47.9 (52.0)	63.6 (70.0)
Carbohydrate[2] (%)	86.8 (94.4)	35.7 (39.5)	20.2 (23.2)
Crude Fiber (%)	5.6 (6.1)	3.7 (4.0)	4.1 (4.5)

[1] Percentage based on wet weight basis.

[2] Carbohydrate includes contribution from fiber.

[3] Product specification obtained from Central Soya Company, Fort Wayne, IN

[4] Numbers in the parenthesis are composition based on dry weight.

Table 5.2. Color of ingredients

Color	ASPF	DSF	SPC
Lightness (L*)	82.7	93.9	92.7
Redness (a*)	12.1	-1.6	-0.6
Yellowness (b*)	23.0	12.7	10.7
Hue angle	62.2	97.0	93.3
Chroma	26.0	12.8	10.7

Table 5.3. Treatment effects on color of cooked pasta

	L*	a*	b*	Hue angle	Chroma
Levels of soy proteins	**	**	ns	**	ns
0% Soy proteins	40.5[c]	21.6[a]	34.1	57.7[c]	40.4
15% Soy proteins	42.0[c]	19.1[b]	35.3	61.4[b]	40.3
30% Soy proteins	45.9[b]	19.1[b]	36.4	62.4[b]	41.5
45% Soy proteins	48.4[a]	17.0[c]	36.7	64.9[a]	40.3
LSD	2.2	1.6	2.0	1.2	2.4
Types of protein[1]	ns	ns	ns	**	ns
DSF	44.4	19.7	34.9	60.5[b]	40.2
SPC	44.0	18.7	36.3	62.6[a]	41.0
LSD	1.6	1.1	1.4	0.8	1.7
Interaction	ns	*	ns	**	ns

* $p<0.05$; ** $p<0.01$; ns = no significant difference.

[1] DSF= Defatted soy flour; SPC= Soy protein concentrate.

[a-c] Means with the same letter in the same column within a treatment indicate no significant difference ($p<0.05$).

Table 5.4. Color values of cooked pasta made from ASPF as affected by level of DSF and SPC substitution

Treatments	L*	a*	b*	Hue angle	Chroma
Control	40.6	21.6	34.1	57.7	40.4
	(1.4)	(2.2)	(2.0)	(4.0)	(3.0)
15% DSF	41.9	18.7	35.0	61.6	39.8
	(1.9)	(2.3)	(4.0)	(5.9)	(2.3)
30% DSF	44.6	19.6	35.0	60.7	40.2
	(1.8)	(2.9)	(2.7)	(5.4)	(1.2)
45% DSF	48.9	18.9	35.6	62.1	40.4
	(0.8)	(3.3)	(0.6)	(4.6)	(1.1)
15% SPC	42.0	19.5	35.6	61.1	40.7
	(3.1)	(2.2)	(5.4)	(4.6)	(3.6)
30% SPC	47.2	18.5	38.4	64.0	42.8
	(3.1)	(2.2)	(4.5)	(4.9)	(3.6)
45% SPC	47.9	15.2	37.2	67.7	40.3
	(2.5)	(2.6)	(2.7)	(4.9)	(1.7)

Numbers in parenthesis are standard deviation.

Table 5.5. Treatment effects on cooking characteristics of cooked pasta

	Cooking loss (%)	Cooking yield (%)	Firmness (N)	Stickiness (Ns)	Cohesiveness	Springiness (mm)
Levels of proteins	*	*	**	**	ns	*
0%	9.9 [d]	198.5 [c]	1.8 [a]	7.8 [a]	0.59	1.18[a]
15%	11.4 [c]	201.2 [bc]	1.0 [b]	6.8 [a]	0.58	1.15 [a]
30%	12.8 [b]	207.1 [ab]	0.7 [c]	3.7 [b]	0.57	1.16 [a]
45%	16.2 [a]	210.7 [a]	0.4 [d]	3.7 [b]	0.55	1.07 [b]
LSD	1.1	8.0	0.2	1.3	0.03	0.07
Types of protein [1]	ns	ns	ns	ns	ns	ns
DSF	12.4	202.0	1.0	5.8	0.57	1.13
SPC	12.7	206.7	1.0	5.1	0.58	1.15
LSD	0.8	5.6	0.1	0.9	0.02	0.04
Interaction	ns	ns	ns	ns	ns	ns

* $p<0.05$; ** $p<0.01$; ns = significant difference..

[1] DSF= Defatted soy flour; SPC= Soy protein concentrate.

[a-d] Means with the same letter in the same column within a treatment indicate no significant difference ($p<0.05$).

Table 5.6. Cooking quality of cooked pasta made from ASPF as affected by level of DSF and SPC substitution

Treatments	Cooking loss (%)	Cooking yield (%)	Firmness (N)	Stickiness (Ns)	Cohesiveness	Springiness (mm)
Control	9.9	198.5	1.8	7.8	0.59	1.18
	(0.4)	(2.4)	(0.2)	(1.4)	(0.03)	(0.02)
15% DSF	11.2	200.4	1.0	7.5	0.57	1.16
	(0.5)	(3.3)	(0.1)	(0.5)	(0.03)	(0.02)
30% DSF	12.6	200.7	0.8	4.1	0.56	1.15
	(1.2)	(1.9)	(0.1)	(0.7)	(0.04)	(0.04)
45% DSF	15.8	208.5	0.4	4.1	0.54	1.07
	(1.1)	(5.6)	(0.0)	(0.8)	(0.04)	(0.06)
15% SPC	11.5	202.0	1.1	6.2	0.58	1.14
	(0.4)	(1.8)	(0.2)	(1.9)	(0.02)	(0.02)
30% SPC	12.9	213.5	0.6	3.3	0.58	1.14
	(1.3)	(3.5)	(0.2)	(0.8)	(0.02)	(0.05)
45% SPC	16.6	212.9	0.4	3.3	0.57	1.09
	(0.8)	(17.1)	(0.1)	(0.6)	(0.02)	(0.04)

Numbers in parenthesis are standard deviation.

Table 5.7. Treatment effects on protein and β-carotene content of cooked pasta

	Protein (%db)	β-carotene (mg/100g dry weight)	Retinol activity equivalent
Levels of proteins	**	**	**
0%	1.9 [d]	9.0 [a]	750 [a]
15%	9.6 [c]	7.8 [a]	652 [a]
30%	18.8 [b]	4.1 [b]	345 [b]
45%	28.1 [a]	2.9 [b]	244 [b]
LSD	0.7	2.6	215
Types of protein [1]	**	ns	ns
DSF	13.3 [b]	6.1	510
SPC	15.9 [a]	5.8	485
LSD	0.5	1.8	152
Interaction	**	ns	ns

* $p<0.05$; ** $p<0.01$; ns = no significant difference.

[1] DSF= Defatted soy flour; SPC= Soy protein concentrate.

[a-d] Means with the same letter in the same column within a treatment indicate no significant difference ($p<0.05$).

Table 5.8. Composition of dried sweetpotato pasta

Treatments[1]	Moisture content ^{ns} (%)	Protein (% db)	β-carotene (mg/100 g)	Retinol activity equivalent[2]
Control	11.4	1.9	9.0	751
15% DSF	10.5	8.9	7.9	658
30% DSF	11.5	16.9	4.4	372
45% DSF	12.2	25.5	3.2	264
15% SPC	11.1	10.4	7.6	646
30% SPC	11.0	20.6	3.9	321
45% SPC	11.4	30.7	2.7	224

[1] DSF= Defatted soy flour; SPC= Soy protein concentrate.

[2] Retinol activity equivalent (RAE): 1 μg RAE = 1 μg retinol = 12 μg β-carotene

Table 5.9. Correlation coefficient among cooking characteristics of cooked pasta

	Cooking loss	Cooking yield	Firmness	Stickiness	Cohesiveness
Cooking yield	0.49*				
Firmness	-0.84**	-0.56**			
Stickiness	-0.75**	-0.58**	0.76**		
Cohesiveness	-0.31	-0.08	0.41	0.02	
Springiness	-0.44*	-0.20	0.43	0.74**	0.74**

Table 5.10. Cooking characteristics of different types of pasta

Cooking characteristics	Wheat noodle	Rice noodle	Experimental pasta 1[1]	Experimental pasta 2[2]	Experimental pasta 3[3]
Color values "L*"	75.4	74.7	40.6	41.9	42.0
"a*"	2.2	-2.1	21.6	18.7	19.5
"b*"	13.3	2.1	34.1	35.0	35.6
Hue angle	80.6	136.3	57.6	61.9	61.3
Chroma	13.5	3.0	40.4	39.7	40.6
Cooking time (min)	7.0	4.0	5.0	5.0	5.0
Cooking loss (%)	3.4	2.6	9.9	11.2	11.5
Cooking yield (%)	231.1	271.2	198.4	200.4	202.0
Firmness (N)[4]	9.5[5]	2.3	5.4	3.0	3.3

[1] Pasta made from 100% ASPF with the dimension 2mm diameter.

[2] Pasta made from ASPF fortified with 15% DSF with the dimension 2mm diameter.

[3] Pasta made from ASPF fortified with 15% DSF with the dimension 2mm diameter.

[4] Based on 3 strands of noodle.

[5] Based on 1 gm of sample.

CHAPTER 6

SUMMARY AND CONCLUSION

Sweetpotato flour prepared from roots of orange flesh sweetpotato roots (Beauregard cultivar), high in β-carotene, fiber and mineral contents, could be used as a main ingredient for production of pasta. Pasta is a staple food in many countries and could be used as a vehicle to deliver the nutrients from sweetpotato to consumers. Pasta could be made from sweetpotato flour by using the extrusion method; however, other ingredients including tapioca flour, wheat gluten or wheat protein concentrate, xanthan gum, ascorbic acid, and monoglyceride need to be added for improving the quality of the cooked product.

However, pasta made from 100% modified sweetpotato flour (MSPF) by the steaming method without any additives could yield a product with the lowest cooking loss and the highest firmness. Addition of 30% defatted soy flour (DSF) increased protein content up to 11 times as compared to that of pasta made from 100% MSPF.

Sweetpotato flour modified with sodium hypochlorite solution under alkaline condition (MSPF) or just treated with alkaline solution (ASPF) improved the pasting properties of sweetpotato flour. Pasting viscosity of MSPF increased whereas that of MSPS decreased. This is due to the composition of flour and starch. MSPF and ASPF were selected to produce pasta to keep sweetpotato nutrients in pasta. The results showed that there was no significant difference among cooking characteristics of pasta made from either 100% MSPF or 100% ASPF.

Pasta made from ASPF by the extrusion method yielded the lowest cooking loss and the highest firmness of cooked products. Soy protein concentrate (SPC) and DSF could be fortified up to 15% in pasta formulation. Pasta fortified with 15%DSF or 15% SPC increased protein content up to 8.9 or 10.4%, respectively. The β-carotene contents of both dried pasta were approximately 7.8 mg/100g.

In conclusion, both native sweetpotato flour and modified sweetpotato flour with or without treatment of sodium hypochlorite could be used to make pasta. Pasta products made from both 100% MSPF and 100% ASPF were a good source of β-carotene and fiber. Fortification of soy protein and whey protein could increase the protein content and improve nutritional quality of sweetpotato pasta.