Agricultural Engineering Today Vol. 31(3 & 4): 06-15, 2007

Strategies for the Production of Starch Noodles: A Review

Balasubramanian S[1*] and Viswanathan R[2]

ABSTRACT

Starch noodles produced from purified starch from various plant sources, are a major category of Asian noodles. Pregelatinized starch is used as a binder mixed with ungelatinized starch to facilitate extrusion or sheeting to produce noodles in the absence of gluten of wheat. The utilization of different raw materials, legume starches tuber starches, rice flour and tuber-legume starch blends in the preparation of starch noodles have been studied. The ideal starch base is one with a Type C viscoamylogram pasting profile characterized by the absence of a peak and a viscosity that remains constant or even increases during continued heating and shearing during noodle making, indicative of good hot-paste stability. This paper deals in detail the starch noodle production.

Key Words: Starch noodles, Glass noodles, transparent noodles, Starch, Amylose, Amylopectin, Pasta.

Introduction

Noodles are an important part in the diet of many Asians. It is believed that noodles originated in China as early as 5000 BC, then spread to other Asian countries and world. Many varieties of noodles are produced with different composition, method of preparation and presentation depending on regional preference (Edwards et al 1996). In recent years, noodles have played an important role in the human diet, especially in Asian countries such as Japan, China, Taiwan, Korea, Vietnam, Thailand and India. The different kinds of noodles classified according to raw material used, noodle size, manufacturing process and finished products are shown in Table 1. Based on raw material used noodles are classified into two types: the protein-based and the starch-based noodles. Protein-based noodles are from wheat (Noda et al 2001, Janto et al 1998). Starch-based noodles are from mungbean (Galvez et al 1994), pigeon pea (Singh et al 1989), red bean (Lii and Chang 1981), sweet potato (Collado and Corke 1997, Collado et al 2001), sorghum (Beta and Corke 2001), potato (Kim and Wiesenborn 1996, Peng et al 1997) sweet potato, maize and cassava (Kasemsuwan et al 1998).

Starch noodles, produced from purified starch from various plant sources, are a major category of Asian noodles. In the absence of gluten, pregelatinized purified starch is used as a binder mixed with ungelatinized starch to facilitate extrusion on sheeting to produce noodles. The utilization of different raw materials such as rice flour (Juliano 1993), legumes (Singh *et al* 1989, Galvez *et al* 1994, Gujska et al 1994, Jin et al 1994) and tuber and tuber-legume starch blends (Kim and Wiesenborn 1996, Collado and Corke 1997) has been studied. From these studies, it was found that the ideal starch base is one with a Type C viscoamylogram pasting profile characterized by the absence of a peak and a viscosity that remains constant or even increases during continued heating and shearing, indicative of good hot-paste stability. Type C starches show restricted swelling and behave like chemically cross-linked starches that exhibit reduced swelling and solubilization (Schoch and Maywald 1968). Sweet potato noodles are extensively produced in China, where it is estimated that 28% of the processed sweet potato is made into starch noodles (Wang et al 1998). Studies on food products based on root crops are of interest to many developing countries because crops play a vital role in food security (Oke 1990), such as substitution for expensive wheat imports. Sweet potato noodles are widely consumed in Korea, Vietnam, and Taiwan (Jeong 1992, Quach 1992). Different types of starch and their characteristics are given in Table 1. Starch noodles are white in

[1*] Scientist (SS), Food Grains and Oilseeds Processing Division, Central Institute of Post Harvest Engineering and Technology, Ludhiana-141 004, India, *Email: balaciphet@yahoo.com; [2] Professor and Head, Department of Food and Agricultural Process Engineering, Agricultural Engineering College and Research Institute, Tamilnadu Agricultural University, Coimbatore-641003, India.

Table 1. Classification of noodles based on various criteria and characteristics

Criteria	Class /Type	Characteristics
Raw material		
	Soft wheat flour - Japanese noodles (udon)	White or creamy white in color and soft texture
	Hard wheat flour - Chinese noodles (ra-men, chuka, ramen, chuka-soba)	Light yellow in color and a little stiff in texture
	Buckwheat (mixed with wheat flour) - Buckwheat noodles (soba)	Light brown or gray in color with a unique taste and flavor
	Rice flour - mien, bihon, beehon, bifun - knanom-jeen - vermicelli	White to yellow color and opaque with tender texture
	Mungbean starch - glass noodles	Transparent and firm texture
	Sweetpotato starch	Transparent and elastic
	Other starches: - Potato, Canna	
Noodle size		
	Very thin - So-men	1.0-1.2 mm strand width
	Thin - Hiya-mugi	1.3-1.7 mm strand width
	Standard - Udon	2.0-3.8 mm strand width
	Flat - Hira men	5.0-7.5 mm strand width
Process		
	Type of binders - Protein: wheat flour noodles - Pregelatinized starch: starch noodles	
	Strand making - Sheeting & cutting: So-men, Udon - Extrusion: Rice noodles	
	Equipment - Handmade: Tenobe so-men - Machine-made: Udon, Hira-men	
Product form		
	Fresh and uncooked	
	Cooked noodles (Boiled or steamed)	
	Frozen boiled noodles	
	Dried noodles	
	Instant noodles	

Source: Zhenghong Chen (2003)

colour, and on cooking becomes soft and transparent are called as transparent noodles or glass noodle (Timmins et al 1992, Galvez et al 1994).

Starches

Starches are the major storage polysaccharides in foods of plant origin. The major botanical and commercial sources of starches are cereals, tubers, roots and pulses. Native and modified starches serve as vital ingredients of many fabricated foods. Starches are α-glucans composed basically of two homopolymers of D-glucans -amylose and amylopectin. Amylose is a linear polymer composed of glucopyranose units linked through α-D-(1$\rightarrow$4) glycosidic linkages. Amylopectin is a branched polymer with one of the highest molecular weights known among naturally occurring polymers, and is composed of glucopyranose units linked by α -D-(1$\rightarrow$4) glycosidic linkage. For approximately every 20-30 glucopyranose residues, a branch point occurs, where a chain of α-D-(1$\rightarrow$4)-glycopyranosyl units is linked to the C-6 hydroxymethyl position of glucose residue through an α-D-(1$\rightarrow$6) glucosidic linkage. Starches exist naturally in the form of discrete granules with in plant cells. These granules are viewed as partially amorphous polymeric systems. The crystalline character of starches arises from the organization of the amylopectin molecules within the granules, while amylose largely makes up the amorphous regions that are randomly distributed between the amylopectin clusters (Blanshard 1987, Zobel 1988).

Cooking of processing normally causes starch gelatinization, i.e. irreversible swelling or even disruption of starch granules, depending upon the severity of the treatment applied. The behaviour of gelatinized starches on cooling and storage, termed as retrogradation, is of great interest, since it profoundly affects quality, acceptability and shelf life of starch-containing foods (Biliaderis 1998). Starch molecules in pastes or gels associate on ageing, resulting in effects such as precipitation, gelation, and changes in consistency and opacity. Crystallites begin to form eventually and this is accompanied by gradual increases in rigidity and phase separation between the polymer and solvent (syneresis). For common starches containing both amylose and amylopectin, a composite gel network forms, consisting of swollen amylopectin-enriched granules filling and interpenetrating amylose gel matrix (Orford et al 1987, Miles et al 1985, Morris 1990). During long-term storage, amylopectin recrystallizes, increases the rigidity of the swollen granules and reinforces the continuous amylose phase. The effect of retrogradation in starch-based products is desirable as well as undesirable. The starch retrogradation contributes significantly to staling or undesirable firming of bread and other starch based products (D'appolonia and Morad 1981, Seow and Thevamalar 1988) requiring low-temperature storage. However, retrogradation is sometimes promoted to modify the structural, mechanical or organoleptic properties of certain starch based products such as breakfast cereals, pasta, noodles and parboiled rice, since retrogradation results in hardening and reduced stickiness (Colonna and Mercier 1985). Freezing/thawing, which accelerated retrogradation, is applied to mashed potatoes to decrease the amount of soluble starch and to improve the consistency of the reconstituted products; i) Japanese 'Harusame' noodles to reduce stickiness to obtain a characteristic chewiness (Watanabe 1981) and ii) Chinese vermicelli (a type of rice noodle) strands to attain the desired textural characteristics (Seow and Teo 1996).

The different methods to study starch retrogradtion is classified as (i) macroscopic techniques, which monitor alternation in physical properties as manifestation of retrogradation such as mechanical and textural changes, and (ii) molecular techniques, which study changes in starch polymer conformation or water mobility in starch gels at molecular levels. Thus, rheological techniques, sensory evaluation of texture, differential scanning calorimetry (DSC), light scattering and turbidometry are used to study the macroscopic manifestation of retrogradation, while other techniques such as X-ray diffractometry, nuclear magnetic resonance spectroscopy (NMR), vibrational spectroscopy (e.g. Raman Spectroscopy) and Fourier transform infra-red (FT-IR) spectroscopy are used to study molecular techniques. The chemical characteristics and properties of starches, starch fractions and starch granules are indicated in Tables 2, 3 and 4.

Starch Noodles

Rice protein lacks the functionality of wheat gluten in making cohesive dough structure for the preparation of noodles. In order to create a uniform matrix in which starch granules are embedded, it is common to subject at least a part of the rice flour to pregelatinization to create a binder for the remaining flour. The conventional process for making rice noodles involves soaking ground rice for several hours, steam cooking the rice slurry to gelatinize the rice starch, kneading the slurry to obtain a cohesive dough, extruding the dough and finally, subjecting the extruded noodle for surface gelatinization in boiling water or steam to improve noodle stability and texture (Juliano and Sakurai 1985). A number of alternative, time saving methods have been reported for improving and simplifying the process for noodle making. Dry milled flours have been used instead of wet-milled starch for rice pasta preparation (Resmini et al 1979). Lee and Kim (1981) reported that a flour mixture of rice, popped rice, wheat flour, and xanthan gum improved the noodle-making properties and cooking quality. Toh (1997) patented a process for producing instant rice noodles by flour with hot

Table 2. Chemical characteristics of starches obtained from various sources

Starch	Amylose, %	Lipids, %	Protein, %	P, %
Corn[a]	28	0.8	0.35	0.00
Waxy corn[a]	<2	0.2	0.25	0.00
High-amylose corn[a]	50-70	nd	0.5	0.00
Wheat[a]	28	0.9	0.4	0.00
Potato[a]	21	0.1	0.1	0.08
Tapioca[a]	17	0.1	0.1	0.00
Mung bean[b]	39	0.3	0.3	nd

Source: a: BeMiller and Whistler (1996), b: Hoover et al (1997), P: Phosphorus, nd: not determined

Table 3. Some important physicochemical characteristics of amylose and amylopectin

Property	Amylose	Amylopectin
Molecular structure[a]	Linear (a-1,4)	Branched ((a-1,4; (a-1,6)
Molecular weight[b]	~106 Daltons	~108 Daltons
Degree of polymerization[a]	1500-6000	3×105-3×106
Helical complex[b]	Strong	Weak
Iodine colour[a]	Blue	Red purple
Dilute solutions[a]	Unstable	Stable
Retrogradation[b]	Rapidly	Slowly
Gel[a]	Stiff, irreversible	Soft, reversible
Film[a]	Strong	Weak and brittle

Source: a: Jane (2000), b: Zobel (1988)

Table 4. Characteristics of some starch granules

Starch	Diameter, µm		Shape
	Range	Mean	
Corn[a]	2-30	10	Round, polygonal
Waxy Corn[a]	3-26	10	Round, polygonal
Wheat[a]	1-45	8	Round, lenticular
Potato[a]	5-100	28	Oval, spherical
Tapioca[a]	4-35	15	Oval, truncated
Mung bean[b]	7-26	NA	Oval round

Source: a: Swinkels (1996), b: Hoover and others (1997), NA: not available

water to obtain a dough, extruding the dough to form noodles, steaming the noodles, blanching the steamed noodles in hot water, and finally, drying the noodles to a moisture content ≤ 15% by weight. The noodles had a firm clear spring bite, smooth mouthfeel and low cooking loss. The degree of pregelatinization of flour plays a very important role in imparting desirable noodle texture. Although some level of gelatinization is required to produce the binding effect during extrusion, excessive gelatinization causes extremely high extrusion pressures (Juliano and Sakurai 1985). Resmini et al (1979) reported that rice pasta made with 7% pregelatinized rice flour produced much better quality noodles than with 100% pregelatinized or raw rice flour. Increasing the proportion of gelatinized flour from 7 to 15% did not further improve the cooking quality the network compactness of the cooked noodles. Traditionally, rice noodles are made from long-grain rice with intermediate to high amylose content (>22% amylose) (Kohlwey et al 1995). A highly significant correlation was found between high amylose and general acceptability. Chun and Luh (1980) reported that swelling capacity of starch and amylose-amylopectin ratio are the two major factors affecting rice noodle quality. Bhattacharya et al (1999) studied eleven rice genotypes with diverse rapid visco analyzer (RVA), for pasting characteristics, physico-chemical and gel textural characteristics relative to their suitability for making rice noodles. Apparent amylose content of rice highly correlated with swelling power, flour swelling volume, noodle hardness, gumminess, chewiness and tensile strength of noodles prepared. Solubility showed an inverse relationship with the pasting parameters and noodle rehydration and a positive relationship with cooking loss, noodle hardness, and gumminess. Flour swelling volume and most of the pasting parameters and textural parameters

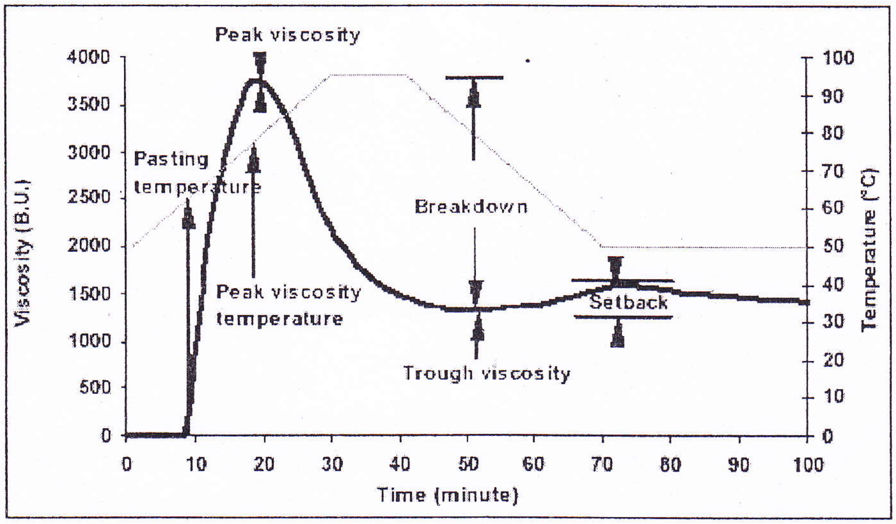

Fig. 1: Rapid visco analyser graph for potato starch (4%, w/v) Source: Zhenghong Chen (2003)

Starch

↓

5 % Gelatinization | 95 % Starch

↓

Kneading keep at 40°C

↓

Extrusion by gravity

↓

Cooking, gelatinization

↓

Draining with cold water

↓

Cooling at 4°C

↓

Freezing at -5°C

↓

Drying

↓

Packing

Fig. 2: A typical Starch noodle production

of gels formed in rapid visco analyser canister were well correlated with actual noodle texture. Rapid visco analyser graph of potato starch is shown in Fig. 1. Starch noodle production flow chart is given in Fig. 2.

*Clear noodles made from mung bean (*Vigna radiata*) starch are popular in oriental foods. The noodles are uniquely translucent and resilient after cooking, have a bland taste. The clear noodle also called as glass noodles are expensive due to tedious processing methods. Clear noodles are also prepared with other starches such as Canna, red bean, sweet potato, pigeonpea, and modified starches (Lii and Chang 1981, Singh et al 1989, Kasemsuwan et al 1998).*

Sweet potato starch has limited use in the Philippines, but modification of its properties by hydrothermal treatment (Stute 1992) makes it more suitable for use in traditional noodles. In the Philippines, rice flour, maize flour, mung bean and starch are used for starch noodles locally known 'Bihon' for those with thin strands and 'Pancit malabon' those with thick strands. 'Sotanghon' the high-quality noodles from mung bean are the most expensive starch noodles, which are known for their high tensile strength, clarity and chewy texture (Collado et al 2001). Starches made into noodles offer certain nutritional benefits to consumers. Bihan noodles from rice have been demonstrated to lower glycemic index of diabetic patients (Panlasigui et al 1990). Starch noodles are retrograded and are, therefore, a source of resistant starch. There is considerable interest in the nutritional implication of resistant starch in foods, since relatively slow rate of starch hydrolysis in the gastrointestinal tract of humans show some physiological effects on dietary fibre (Englyst et al 1992).

Texture of cooked noodles is the most critical characteristic that determines consumer acceptance of the product. The direct and ultimate method for assessing texture of noodles is by sensory evaluation. However, sensory evaluation is impractical when sample size is limited or when large members of line to be evaluated in breeding programs (Edwards et al 1996). Due to the constraints of sensory evaluation, a number of instrumental methods have been developed for measuring the textural properties of noodles that are less time-consuming more cost-effective and require small sample size (Lii and Chang 1981). Bhattacharya et al (1999) showed textural parameters of gels formed in the rapid visco analyser, which canister correlated highly with the pasting characteristics of wheat starch, and could be used as an indirect measure of textural quality rice starch noodles and also to identity the specific characteristics responsible for producing superior quality rice starch noodles. The various

Table 5. The commonly used modifications of starch in food application

Type of modification	Main objectives	Treatments
Pregelatinized starch	Cold water dispersibility	Drum-drying, Extrusion
Low-viscosity starches		
a. Dextrins	Range of lower viscosity stability	Dry heat treatment with acid
b. Acid-modified starch	High gel tendency	Acid hydrolysis (suspension)
c. Oxidized starch	Improved viscosity stability	Oxidation (in suspension or paste)
d. Enzymatically modified starch	Lower viscosity	Alpha-amylase (paste)
Crosslinked starch	Modification of cooking characteristics	Crosslinking in suspension
Stabilized starch	Improved viscosity stability	Esterification, Etherification
Combinations of modifications 1, 2, 3 and/or 4	Combinations of objectives 1, 2,3 and/or 4	Combinations of treatments 1,2,3 and/or 4
Starch sugars	Sweet saccharides	Acid and/or enzymes

Source: Swinkels (1996)

modifications of starches for food application are shown in Table 5.

Mung bean starch has been reported as an excellent raw material for starch noodles (Lii and Chang 1991). However, starch noodles have been prepared from various other plant sources including red bean (Lii and Chang 1981), pigeon pea (Singh et al 1989), potato (Kim and Wiesenborn 1996), sweet potato (Collado and Corke 1997), and sorghum (Kim and Wiesenborn 1996, Beta and Corke 2001). Starch noodles are prepared by mixing purified starch with pregelatinized starch as a binder, mixing to dough and extruding into boiling water. Starch from potatoes and blends of mung bean and potato starch have been used to make starch noodles although the physico-chemical characteristics of potato starch differ from those of mung bean starch (La Bell 1990, Kim and Wiesenborn 1996). Potato starch is preferable over corn and cereal starches for starch noodle manufacture, because of its neutral taste, much higher transparency and flexibility of the noodles.

Isolation and Purification of Starches

Mung bean, sorghum and potato starches are isolated and purified using different procedures by Wiesenborn et al (1994), Schoch and Maywald (1968) and Galvez and Resurrecsion (1993), Perez et al (1993), Zhao and Whistler (1994) and Wu et al (1995). The tubers of potato and sweet potato were processed into starch. The tubers were washed thoroughly, shredded, macerated with water filtered and passed through sieve. The filtrate was allowed to settle few hours at room temperature. The supernatant was decanted and discarded. The sedimented starch was resuspended in water filtered and dried in a convention oven at 50°C. The legume samples were steeped in water overnight, washed, ground and filtered. However, sorghum is steeped in NaOH (0.25% w/v) at 5°C for 24 h. After washing the steeped grains were ground and filtered. The sedimented starch washed and dried in air oven at 40°C for 24 h. The size and shape of isolated starch granules were examined under light microscope.

Starch Noodle Preparation

Starch noodles are prepared according to procedure described by Lii and Chang (1981). Ninety-five parts of dry starch are mixed with five parts of cooked starch on dry weight basis, which was prepared by boiling the dry starch and water (1:7 w/v) mixture for 5 min. to form dough. The dough, which contains about 55% moisture is extruded with a cylinder type extruder with a hole of about 2 mm diameter. The extruded noodles are immersed in boiling water for 3 min, and in cold water for 3 min. The noodles are separated and air dried at room temperature for 1 day. The dried noodles are stored in sealed polyethylene bags.

Cooked Starch Noodle Analysis

The cooking procedure of starch noodle is a modified form of AACC (1983). The other physical tests of starch noodles, such as cooking test (Vasiljevic and Banasik 1980), cooking loss, starch noodle firmness (Bahnassey and Khan 1986), starch noodle stickiness (Grant et al 1993) using an Instron Universal Testing Instrument are determined.

Sensory Evaluation

Starch noodles are evaluated for glossiness, transparency, firmness, stickiness and elasticity by trained panelists (Meilgaard et al 1991). Noodles made from the small granule starches exhibit high transparency and flexibility of the dried noodles, low cooking loss, low swelling index and high elasticity of the cooked noodles. Obviously, the starch noodle quality also depends on the starch origin. Other properties of starch granules such as granule density, granule shape and the smoothness of the granule surface also affect the starch noodle quality. All commercial starches, cannot be used for starch noodle preparation because they wither lack the fluidity to form the constant long noodle preparation because they either lack the fluidity to form the constant long noodle strands or they form strands which are too sticky to separated. Thus, the proper processibility is an important prerequisite of the raw starch for starch noodle production. The proper selection depends on the behavioral characteristics and the cost of the starch (derivative) with respect to application. Unfortunately, not enough attention has been paid by food scientists towards the processibility of starch in starch noodle production.

Conclusions

The broad variation in physical and chemical properties of rice starches had a marked influence on the textural quality of the starch noodles. Amylose content was the major factor affecting the pasting and textural properties of starch although solubility and swelling behaviour of the starch also has significant effects. The use of RVA in conjugation with DSC and other physico-chemical tests provides, prediction of textural quality of noodles. Starches made into noodles offer certain nutritional benefits.

References

AACC 1983. Approved of the American Association of Cereal Chemists. Method 16-50. St. Paul, MN

Bahnassey Y, Khan K 1986. Fortification of spaghetti with edible legumes, II. Rheological, processing, and quality evaluation studies. Cereal Chem 63(3):216-219

BeMiller JN, Whistler RL 1996. Carbohydrates. In: Fennema OR, (ed), Food Chemistry. 3rd (edn), New York, Marcel Dekker, Inc, p 191-195

Beta T, Corke H 2001. Noodle quality as related to sorghum starch properties. Cereal Chem 78:417-420

Bhattacharya M, Zee SY, Corke H 1999. Physico-chemical properties related to quality of rice noodles. Cereal Chem 76 : 861-867

Biliaderis CG 1982. Physical characteristics, enzymatic digestibility, and structure of chemically modified smooth pea and waxy maize starches. J Agric Food Chem 30:925-930

Blanshard JMV 1987. Starch granule structure and function: A physico-chemical approach. In : Starch properties and potential. Galliard TG Chichester (ed), John Wiley & Sons, p 16-54

Chun SY Luh BS 1980. Chemical, physical and cooking properties of rice vermicelli. In: 18th Rice Technol Working group, Texas A&M university, Collage Station, TX

Collado LS, Corke H 1997. Properties of starch noodles as affected by sweetpotato genotype. Cereal Chem 74: 182-187

Collado LS, Mabesa LB, Oates CG, Corke H 2001. Bihon-type noodles from heat-moisture treated sweetpotato starch. J Food Sci 66: 604-609

Colonna P, Mercier C 1985. Gelatinization and melting of maize and pea starches with normal and high-amylose genotypes. Phytochem 24:1667-1674

D'appolonia BL, Morad MM 1981. Bread staling. Cereal Chem 58:186-190

Edwards NM, Scanlon MG, Kruger JE, Dexter JE 1996. Oriental noodle dough rheology: Relationship to water absorption, formulation, and work input during dough sheeting. Cereal Chem 73:708-711

Englyst HN, Kingnan SM, Cummings JH 1992. Classification and measurement of nutritionally important starch fractions. Eur J Clin Nutr 46 (2) 33-35

Galvez FCF Resurreccion AVA 1993. The effects of decortication and method of extraction on the physical and chemical properties of starch from mungbean (vigna radiate (L.) Wilezec). J Food Proc Press 17:93-107

Galvez FCF, Resurreccion AVA, Ware GO 1994. Process variables, gelatinized starch and moisture effects on physical properties of many bean noodles. J Food Sci 59:378-381, 386

Grant LA, Dick JW, Shelton DZ 1993. Effects of drying temperature, starch damage, sprouting, and additives on spaghetti quality characteristics. Cereal Chem 70:676-684

Gujska E, Reinhard WD, Khan K 1994. Physico-chemical properties of field pea, pinto and navy bean starches. J Food Sci 59:634 –636, 651

Hoover R, Li YX, Hynes G, Senanayake N 1997. Physicochemical characterization of mung bean starch. Food Hydrocolloids 11:401-408

Jane J 2000. Carbohydrates: Basic concepts. In: Food chemistry: Principles and applications, Christen GL, Smith JS (ed), California: Science technology system, p 43-45

Janto M, Pipatsattayanuwong S, Kruk MW, Hou G, McDaniel MR 1998. Developing noodles from US Wheat varieties for the Far East market: Sensory perspective. Food Quality Pref 9: 403-412

Jeong BC 1992. Sweet potato processing, marketing and utilization in Korea. In : Product Development for Root and Tuber Crops. Scott GJ, Wiersema S, Ferguson PI (eds) Vol I.

International Potato Center, Lima, Peru, p 79-85

Jin M, Wi J, Wu X 1994. A study on the properties of starches used for starch-noodle making. In: Proc Symp Exhibition on New Approaches in the Production of Foodstuffs and Intermediate Products from Cereal Grains and Oil Seeds. Xie G, Ma Z (eds) CCOA/ICC/AACC meeting, CCOA: Beijing, p 488-496

Juliano BO 1993. Major processed rice products. In: Rice Human Nutrition. Food and Nutrition Series No 26, Food and Agriculture Organization, Rome

Juliano BO, Sakurai J 1985. Miscellaneous rice products, In: Rice Chemistry and Technology, 2nd edn, Juliano BO (ed), Am Assoc Cereal Chem, St. Paul MN, p 569-618

Kasemsuwan T, Bailey T, Jane J 1998. Preparation of clear noodles with mixtures of tapioca and high-amylose starches. Carb Polym 36: 301-312

Kim SY, Wiesenborn DP, 1996. Starch noodle quality as related to potato genotypes. J Food Sci 61: 248-252

Kohlwey DE, Kendall JH, Mohinda RB 1995. Using the physical properties of rice as a guide to formulation. Cereal Foods World. 40 : 728-732

La Bell F 1990. Potato starch improves oriental noodle texture. Food Process 6: 188-190

Lee KH, Kim HS 1981. Preparation and evaluation of dried noodle product from composite flours utilizing rice and wheat flour. Korean J Food Sci Technol 13:6-14

Lii CY, Chang YH 1991. Study of starch in Taiwan. Food Rev Int 7:185-203

Meilgaard M, Civille GV Carr BT 1991. Sensory evaluation techniques, 2nd edn, CRC Pres Inc. Boca Raton, FL

Miles MJ, Morris VJ, Orford PD, Ring SG, Carol V, 1985. The roles of amylose and amylopectin in the gelation and retrogradation of starch. Carb Res 135:271-278

Morris VJ 1990. Starch gelation and retrogradation. Trends Food Sci Technol 1:2-6

Noda T, Kobayashi T, Suda I 2001. Effect of soil temperature on starch properties of sweet potatoes". Carb Polym 44: 239-246

Oke OL 1990. Food security in developing countries In: Roots, tubers, plantains and bananas in human nutrition. Food and Nutrition Series, No. 24. Food and Agriculture Organization, Rome

Orford PD, Ring SG, Carol V, Miles MJ, Morris VJ 1987. The effect of concentration and botanical source on the gelation and retrogradation of starch. Food Agri 39:169-177

Panlasigui LN, Thomson LU, Jenkins DJA, Juliano BO, Perez CO, Yiu S 1990. Starch digestibility and glycemic response to extruded high amylose and rice noodles. Trans Nat Acad Sci Technol (Manila) 12:109-127

Peng H, Lian R, Toh TS 1997. Instant mungbean or potato starch noodles. Trends Food Sci Technol 8: 249

Perez E, Bahanassey YA Breene WM 1993. A simple laboratory scale method for isolation of amaranthus starch. Starch 5:215-220

Quach N 1992. Cassava and sweet potato processing, marketing and utilization in Vietnam. In: Product Development for Root and Tuber Crops. Scott GJ, Wiersema S, Ferguson PI (eds) Vol 1, International Potato Center (CIP), Lima, Peru

Resmini P, Lenner A, Debernardi G, Gerardo D 1979. Technology and ultrastructure of 'pasta' (noodles) produced with rice flour. Centro Ricerche Soc Braibanti, Milan, Italy

Schoch TJ, Maywald EC 1968. Preparation and properties of various legume starches. Cereal Chem 45:564-573

Seow CC, Teo CH 1996. Staling of starch-based products: A comparative study by firmness and pulsed NMR measurements. Starch/ Starke 48(3): 90-93

Seow CC, Thevamalar K 1988. Problems associated with traditional Malaysian starch-based intermediate moisture foods. In: Food preservation by moisture control, Seow CC (ed), Elsevier Applied Science, London, p 233-252

Singh U, Voraputhaporn W, Rao PV, Jambunathan R 1989. Physico-chemical characteristics of pigeon pea and mungbean starches and their noodle quality. J Food Sci 54: 1293-1297

Stute R 1992. Hydrothermal modification of starches: The difference between annealing and heat moisture treatment. Starch/Starke 6:205-214

Swinkels JJM 1996. Industrial starch chemistry. AVEBE brochure, Foxhol, the Netherlands. p 8-24

Timmins WH, Marter AD, Westby A, Rickard JE 1992. Aspects of sweet potato processing in Sichuan province, People's Republic of China. In: Product Development for Root and Tuber Crops. Scott GJ, Wiersema S, Fergusun PI (eds) Vol.1, International Potato Center (CIP), Lima, Peru

Toh TS 1997. Instant rice noodles. Trends Food Sci Technol 8: 249-251

Vasiljevic S Banasik OJ 1980. Manual of quality testing methods for durum wheat and its products. Dept Cereal Sci Food Technol North Dakota State University, Fargo

Wang S, Song B, Zhang L 1998. Status and prospects of sweet potato processing in China. Paper presented at the SAPPRAD Sweet potato Processing Study Tour and Workshop Pingyin, Shandong Province, China, International Potato Center (CIP):Bogor, Indonesia

Watanabe T 1981. Traditional techniques in Japan for food preservation by freezing, thawing and drying. In: Water activity: influences on food quality. Rockland LB, Stewart GF (ed), Academic Press. New York, p 733-742

Wiesenborn DP, Orr PH, Casper HH, Tarke BK 1994. Relationship between potato starch paste behaviour and selected physico-chemical properties. J Food Sci 58:644-648

Wu H, Yue S, Sun H, Corke H 1995. Physical properties of starch from two genotypes of Amaranthus cruentus of agricultural significance in China. Starch/Starke 47:295-297

Zhao S, Whistler RL 1994. Isolation and characterization of starch from amaranath flour. Cereal Chem 71:392-393

Zhenghong Chen 2003. Physicochemical properties of sweet potato starches and their application in noodle products. Ph.D. thesis. Department of Agrotechnology and Food Sciences, Wageningen University, The Netherlands. ISBN: 90-5808-887-1

Zobel HF 1988. Molecules to granules: A comprehensive starch-Review. Starch/Starke 40:44-50