Characteristics of Clear Noodles Prepared from Edible Canna Starches

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ABSTRACT: Clear noodles were prepared from starches of 3 edible canna cultivars namely, Thai-purple, Thai-green, and Japanese-green. The effects of amount of gelatinized starch, moisture content of dough, and holding temperature after cooking on noodle appearance were investigated. Ten percent gelatinized starch, 55% moisture content, and holding temperature at 4 °C for 24 h gave clear noodles with appearance, cooking loss, and rehydration ratio comparable to commercial mung bean noodles. However, the canna noodles were of inferior tensile strength. Moisture content of the canna noodles was 15.24% to 15.48%. Their chemical compositions on dry weight basis were as follows: 89.41% to 91.63% starch, 0.21% to 0.33% protein, <0.01% lipid, 0.16% to 0.20% ash. Measured diameters of noodles were in the range of 0.73 to 0.88 mm. The cooking losses were 0.93% to 0.55% dry weight, whereas tensile stresses were 17.44 to 22.77 g/mm². The energy values derived from 100 g of canna noodles were 358.48 to 367.84 kcal. Sensory evaluation by descriptive test revealed that there were no significant differences (P ≤ 0.05) in the general acceptability between the canna noodles and the commercial mung bean noodles. By paired-comparison test, however, the commercial mung bean noodle A was more favorable.

Keywords: canna starch, noodle, clear noodle, properties, sensory

Introduction

Clear or “glassy” noodles have translucent and elastic textures after cooking. Many legume starches such as pigeonpea, mung bean, red bean, adzuki bean starches, and other starches such as sweet potato, modified starches have been used for producing clear noodles. Noodles made from red bean starch possessed fairly good quality, but not as good as mung bean starch noodles (Lii and Chang 1981). Singh and others (1989) investigated the potential of pigeonpea starch for noodle preparation. Chiu and Chua (1989) reported the result of replacement of mung bean starch by cross-linked potato and sweet potato starch. Kasemsuwan and others (1998) examined the properties of clear noodles made from native tapioca, cross-linked tapioca, and a mixture of cross-linked tapioca and high-amylose starches. Native and cross-linked tapioca starch alone produced noodles that were too soft and could not be separated into single strands. However, noodles made from a mixture of cross-linked tapioca and 17% high-amylose starches were comparable to the noodles made from mung bean starch.

Mung bean starch has been shown to have unique properties: high amylose content, a C-type Brabender viscosity curve (as classified by Schoch and Maywald 1968), and restricted swelling (Singh and others 1989). Due to these properties, it is an ideal material for clear noodle manufacture. However, it is expensive and thus many attempts as mentioned previously have been made to replace it with other starches. Edible canna (Canna edulis Ker) is a perennial herb of the family Cannaceae, native to the Andean region in South America. This plant has large starchy rhizomes, which are traditionally used as a staple food for Andean people for more than 4000 years. This crop is now cultivated as the source for starch production in small-scale factories in China, Taiwan, and Vietnam. There have been some reports on the physicochemical properties of edible canna starch (Soni and others 1990; Perez and others 1998; Santacruz and others 2002; Thitipraphunkul and others 2003a). The reports indicated the interesting properties of edible canna, especially pasting properties. Soni and others (1990) reported that Brabender viscosity of C. edulis starch is more than 3 times higher than that of maize starch and has much higher viscosity than cassava starch at the same concentration. The canna starches had quite high amylose content (21% to 28%), and their ability to retrograde was at the same level as mung bean starch (Thitipraphunkul and others 2003a). The canna starches seem to possess qualities that make them ideal for clear noodle manufacture. Hence, the objective of this study was to investigate the physicochemical properties and qualities of clear noodles prepared from edible canna starches. To inspect the suitability of canna starch for making acceptable noodles, the commercial clear noodles made from mung bean starch were used as the references.

Materials and Methods

Materials

Three cultivars of edible canna (Thai-purple, Thai-green, and Japanese-green) were grown on experimental plots under identical environmental condition at the Corn and Sorghum Research Center, Kasetsart Univ., Thailand; 10-mo-old rhizomes were harvested for starch extraction. Starch was isolated from the rhizomes according to a procedure described by Thitipraphunkul and others (2003a). Mung bean starch was isolated from mung bean according to a procedure described by Thitipraphunkul and others (2003a). Three brands of commercial mung bean noodles were purchased from local suppliers in Bangkok, Thailand. All the chemicals used in the experiments were analytical grade.
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Chemical compositions of starch and noodles
Standard AOAC methods (AOAC 1990) were used for the measurement of moisture, nitrogen, fat, and ash. Protein was calculated from total nitrogen using a conversion factor of 6.25. Lipid was analyzed following the method of Harrington and Evans (1985). Starch was determined according to the enzyme digestion method of Rasmussen and Henry (1990) with some modifications and by the phenolsulfuric method (Dubois and others 1956). Apparent amylose content was determined by procedures described by Jayakody and Hoover (2002). Energy value of the noodles was calculated based on specific calorific values of each nutritional component.

Pasting properties of starch
Pasting properties of starch slurry at a concentration of 6% (w/w) were determined by using a Rapid Visco Analyzer (RVA-4SA, Newport Scientific, Narrabeen, Australia). The starch slurry was stirred rapidly at 900 rev/min for 10 s before the shear input was decreased and held constant at 160 rev/min. The time for heating and cooling cycles was totally 13 min, starting from 50 °C for 1 min and then heated to 95 °C in 3.7 min and held at 95 °C for 2.5 min before cooling to 50 °C in 3.8 min and held for 2 min. Setback value was calculated by subtracting the viscosity at 7.2 min (the end of holding at 95 °C) from the final viscosity.

Noodle preparation
The process for making canna noodles involves mixing dry and gelatinized starch paste to form a thick slurry, extruding it directly into boiling water to cook, cooling the cooked noodles in cold water, holding them at refrigerated temperature, washing them in cold water, and then drying the washed noodles (Kasemsuwan and others 1998). Both the canna starch and its gelatinized paste were mixed by using a dough paddle and kitchen mixer (Model KSS, Kitchen Aid Mixer, St. Joseph, Mich., U.S.A.) at speed 1 for 1 min, speed 2 for 2 min, and speed 4 for 4 min. Ratios of the raw starch and the gelatinized starch were 90:10, 95:5, and 97:3, and final moisture contents were adjusted to 62%, 66%, and 70%, respectively. The preliminary studies were done on Thai-purple canna starch by using a fabric bag fixed with a perforated stainless-steel plate at the bottom as a noodle-forming device. Subsequently, a hydraulic extruder with a 40-hole (2-mm dia) die was used instead. The noodles were extruded into boiling water, and as soon as they floated, they were transferred and washed repeatedly in 3 cold water baths. They were then hung on bamboo sticks and placed in a freezer or in a cold room (4 °C) for 24 h. After this, they were transferred into water and soaked at room temperature for 1 h. Finally, they were air-dried and then sun-dried on bamboo sticks and stored in plastic bags at room temperature.

Noodle analyses
Morphology. Texture appearances (smoothness, air-bubble, size uniformity) of dried noodles were examined by stereomicroscope. Diameter of the noodles was measured by venier caliper (Mitutoyo Corp. Co., Ltd., Tokyo, Japan). Ten specimens of each sample were measured and the values were averaged.

Tensile strength. Noodles were cooked in boiling, distilled water for 10 min. After cooling at room temperature, the tensile strength was measured using a texture analyzer (TA-XT2i, Stable micro system Co., Ltd., Surrey, U.K.) with parallel friction rollers. For each treatment, 15 specimens were tested at a test speed of 10.0 mm/s and a distance between the 2 grips of 60 mm, and the values were averaged.

Differential scanning calorimetry. Thermal properties of starches and noodle powders were determined by differential scanning calorimeter (DSC)-pyris1 analyzer (Perkin-Elmer Corp., Norwalk, Conn., U.S.A.). Starch (3 mg) was weighed in a DSC pan, and water (6 mg) was added. The pan was sealed and allowed to stand for 12 h at 4 °C. The scanning temperature range and the heating rate were 30 °C to 150 °C and 5 °C/min, respectively. Water (6 mg) was used as a reference. The transition temperatures reported are the onset temperature (T0), peak temperature (Tp), and conclusion temperature (Tf). The enthalpy of gelatinization (ΔH) was expressed in terms of joules per gram of dry starch.

Rehydration test. The rehydration test was performed following the method of Von Loesecke (1945). Noodles (approximately 3 g) were placed in a strainer dripped into a beaker containing 250 mL of boiling water and were cooked for 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, and 11 min. Then the strainer with cooked noodles was soaked and swirled 4 or 5 times in water (25 °C). The water was removed by filtering through Whatman nr 1 filter paper (Whatman Int Ltd, Cambridge, U.K.). The rehydration ratio was calculated as weight of cooked noodles divided by weight of noodles before cooking.

Cooking loss. Cooking loss was determined following the method of Lii and Chang (1981) with some modifications. Noodles (25 g), cut into 3- to 5-cm lengths, were added to a beaker containing 250 mL of boiling water on a hot plate. They were stirred gently with a glass rod. After cooking for 10 min, the noodles were filtered through a nylon screen. The beaker, noodles, and screen were washed with distilled water. The combined filtrate was placed in a dried, tared beaker (Wj) and dried at 80 °C and then 110 °C in an oven to constant weight (Wf). The moisture content of the precooked noodles was Wp. The solid loss during cooking was calculated by the following equation:

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\text{Cooking loss (\%)} = \left(\frac{W_f - W_j}{25 - W_j}\right) \times 100
\]

Sensory evaluation
Canna starches and commercial mung bean noodles were evaluated by 15 trained panel members using the descriptive test for their clarity, flavor, texture, and general acceptability. Each experiment was done in triplicate. Freshly cooked noodles were prepared by soaking them in water at room temperature for 20 min and then boiling for 1 min and cooling in water. The mean scores of each attribute were compared among all samples. The scores if each attribute were as follows:
1. Clarity scores of 1 to 4, varying from opaque, nonglossy to clear and glossy appearance.
2. Flavor scores of 1 to 4, varying from acidic rancidity to natural bland tastes.
3. Texture scores of 1 to 4, varying from soft, crumbly, and aggregate to elastic, resilient, and completely nonaggregated.
4. General acceptability scores from 1 to 5, varying from unacceptable to very acceptable.

The sensory scores were each subjected to analysis of variance (ANOVA) to determine whether there were statistically significant (\(P \leq 0.05\)) differences in sensory attributes. Duncan’s Multiple Range Test was used to determine which of the samples differed significantly. The paired-comparison test of canna noodles and commercial noodles made from mung bean was used by 15 panelists to evaluate sensory attributes of color, flavor, texture, and general acceptability. Each canna noodle was served paired with a commercial noodle at 1 time. The data were then statistically analyzed for significant differences at \(P \leq 0.05\) by using Binomial test.

Results and Discussion

Pasting properties of canna starches
Figure 1 shows the viscosograms of self-extracted and commercial...
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mung bean and 3 cultivars canna starches (6% w/w) determined by a rapid visco analyzer (Newport Scientific). Viscograms of all canna starches displayed high viscosity, no breakdown, relative stability during holding at 95 °C, and high setback. According to Schoch’s classification of viscosity patterns (Schoch and Maywald 1968), canna starches could not be classified specifically into type B (moderate-swelling) or C (restricted-swelling), but their patterns were somewhere between type B and C. The pasting temperatures of canna starches were approximately 74 °C to 75 °C, lower than those of self-extracted (77.5 °C) and commercial (80 °C) mung bean starch. Canna starches showed higher viscosity than mung bean starches. On cooling, all canna starches had higher setback (92 rapid visco unit [RVU] for Thai-green, 65 RVU for Japanese-green, and 83 RVU for Thai-purple) than self-extracted (64 RVU) and commercial (24 RVU) mung bean starches.

Canna starch pastes showed good shear and thermal resistance, similar to the pasting properties of cross-linked and mung bean starches. The withstanding of swollen canna starch granules to shear force and high temperature has been reported in details by Thitipraphunkul and others (2003a). Canna starches also showed significant setback, and their pastes were very clear and elastic. These results confirm that canna starches have sufficient specific characteristics required for making a clear noodle.

Preparation of noodles from canna starches

First, the effects of percentage ratio of gelatinized starch to dry starch (3%, 5%, and 10%), final moisture content of dough (62%, 66%, and 70%), and holding temperature after cooling (–18 °C and 4 °C) on noodle appearance were investigated. The dough at 3% gelatinized starch with all moisture contents could not be extruded from the fabric bag. Due to the low amount of gelatinized starch, the dough was not formed homogeneously and was too hard to be extruded. At higher percentage of gelatinized starch (5%), the dough with moisture contents of 66% and 70% could be extruded, but only short noodles were obtained. For 10% gelatinized starch, the dough with 66% and 70% moisture gave short, nonuniform size, and non-surface smooth noodles, whereas the dough with 62% moisture gave noodles that were long, of uniform size, and of quite smooth surface.

In the manufacturing of starch noodles, retrogradation is achieved by holding at low temperature (–18 °C to 5 °C) for a certain period of time (12 to 24 h) (Galvez and others 1994). In this experiment, turbid-white and spongy texture were observed after holding the cooked noodles at –18 °C for 24 h, whereas the noodles had clear and dense texture when kept at 4 °C. The spongy texture of noodles stored at –18 °C could be attributed to the water expelled from starch gel matrix, which became ice crystals under temperatures lower than the freezing point. This led to the formation of void space within the noodles.

According to the results obtained, preparation of noodles was then preceded by using a hydraulic extruder that could be used for tougher dough. Dough was prepared from materials having gelatinized starch to dry starch at the ratio of 10% with 3 levels of moisture contents (50%, 55%, and 62%). All conditions gave continuously long noodles, but the noodles made from dough with 62% moisture had a rough surface and nonuniform diameter. Consequently, the preparation of noodles from canna starches in the following section was then done by using the percentage ratio of gelatinized starch to dry starch at 10%, moisture content of 55%, and a constant 4 °C after cooking.

Physical properties of canna starch noodles

The physical properties of noodles made from starches of 3 canna cultivars (Thai-purple, Thai-green, and Japanese-green) were compared with those of 3 commercial clear noodles, namely, A, B, and C made from mung bean starch. The appearance of canna starch noodles is shown in Figure 2. All canna noodles were white and semitransparent with uniform size. The physical properties of the canna starch and commercial mung bean noodles are summarized in Table 1.

Size (diameter) of noodles. All commercial mung bean noodles had almost the same size, whereas noodles from canna starches were slightly larger. The size of noodle depended mainly on the diameter of the perforated holes of the extruder’s die and the distance between the die and surface of boiled water. The sizes of all noodle samples, 0.67 to 0.88 mm, were in the range stated by Thai Natl. Standards for starch vermicelli in 1988 (0.5 to 1.5 mm). The differences in size within 1 noodle of canna starch noodles, from 10 points measurement within 15 cm noodle length, were less than ±0.15 mm (data not shown).

Cooking loss. The cooking losses of all canna starch noodles were lower than those of commercial mung bean starch noodles. This might be related to intrinsic properties of canna and mung bean starches and/or might be caused by some variations in the manufacturing processes of each mung bean noodle company and our canna noodle preparation. Sung and Stone (2004) studied the cooking quality of noodles made from legume starches and reported that noodles made from mung bean starch had the lowest cooking loss compared with the noodles from chick pea and pinto bean starches. Loss in weight of noodles during cooking was mostly due to solubilization of loosely bound gelatinized starch on the surface of the noodles. That is, the extent of cooking loss would mainly depend on the degree of starch gelatinization and the strength of the gel network-like structure of the noodles. The latter was determined by chemical compositions, amylose/amylopectin ratio, and molecular structure of the starch. Canna starches were reported to have smaller-sized amyloses and a lower average number chains of branched molecules than mung bean starch (Thitipraphunkul and

Figure 1—Pasting profiles of starch (6%, w/w) measured by rapid visco analyzer.

Figure 2—Appearance of noodles made from canna starches.
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- Tensile strength/tensile stress. Because each of noodle samples had their unique sizes, instead of using the tensile strength, the tensile stress (force per area) was more suitable as a parameter to indicate the strength of noodles. The tensile stresses of commercial mung bean noodles were greater than those of canna starch noodles. The strength of noodles has been attributed primarily to their amylose content (Lii and Chang 1981). The amylose content of canna starches as shown in Table 2 was significantly lower than that of mung bean starch as reported elsewhere, 37% (Kasemsuwan and others 1998) and 30% (Thitipraphunkul and others 2003a).

- Rehydration of dry noodles. The rehydration ratios (the weight of cooked noodles divided by the weight of noodles before cooking) of all noodle samples were not much different, except for the mung bean C noodle, which had a noticeably higher rehydration (Figure 3). The rehydration ratio of the noodles could be used as a parameter to predict the cooking quality of the noodles because the less the degree of hydration, the stronger the noodle texture. Among the mung bean noodle samples, a rehydration ratio of sample A was lower than samples B and C, respectively. These values were consistent with the tensile stresses of noodles (Table 1), that is, sample C of mung bean noodles had the lowest tensile stress followed by samples B and A, respectively.

- Chemical composition of canna starch noodles

Table 2 summarizes the chemical compositions of raw canna starch and canna starch noodles. According to the method of Rasmussen and Henry (1990), the starch content was determined by digesting the sample with \( \alpha \)-amylase and amyloglucosidase and then measuring the reducing sugar and converting the reducing sugar to starch content. It is postulated that a part of retrograded noodles acted as a resistant starch, and when resistant to digestion by the amylase enzymes, the starch contents in noodles were thus lower. On the other hand, when measured by using the phenol sulfuric method, the starch contents in noodle samples were much closer to those found in the corresponding raw starch samples. This implied that the starch in noodles could be greatly hydrolyzed by the acid, comparing by the enzymes. Among the canna, Thai-purple raw starch showed the lowest content of starch. This indicated that raw starch of Thai-purple sample contained the highest amounts of other components that might affect the qualities of its noodles. Other compositions such as lipid and protein existed in very low amounts. Apparent amylose contents of all canna starches were moderately

![Figure 3—Rehydration of dry canna and commercial mung bean noodles.](image-url)
Thermal properties of canna starch noodles

DSC is a thermal analysis method widely used to monitor gelatinization and retrogradation of starch. Controlled heating of a suspension of starch is characterized by an endotherm, reflecting the melting transition of starch (Cui and Oates 1997). Thermal properties of canna starches and their corresponding noodles measured by DSC are summarized in Table 3 (thermograms are not shown here). The melting of canna starches started at 67 °C and ended at 72 °C. The enthalpy (ΔH) of canna starch was in the range of 17 to 18 J/g. Compared with canna starches, the thermograms of canna noodles were flat and broad. The melting transitions of canna noodles were shifted to lower temperatures (Tm = 45 °C to 46 °C) and ended at higher temperatures (Tc = 77 °C to 78 °C), and the enthalpies were very low (2 to 3 J/g), compared with the raw starches. The results indicated that the major part of the semicrystalline structure of starch granules was destroyed when the noodle was cooked in boiled water. The released amylose, amylopectin molecules, and fragments of starch granules were reassociated when kept at 4 °C for 24 h. The association bonds were not strong, as shown by the low values of melting enthalpy.

At a scanning temperature up to 150 °C, no other peak was found. A study on retrogradation of sago starch gelatinized at 160 °C, after keeping at 5 °C for more than 1 h, revealed the 2nd endothermic peak centered around 150 °C (Cui and Oates 1997). This 2nd peak was believed to correspond to the reassociation of amylose (Biliaderis and others 1985). In our study, the noodles were cooked in boiling water for a short time (about 1 min); therefore, the gelatinization might not have been completed. The retrogradation behavior might possibly be different from the completely dispersed starch solution. The reassociation among amylose molecules thus was too low to be identified by DSC.

Sensory evaluations

Descriptive test. The mean scores of 15 panelists are presented in Table 4. The clarity of all canna and commercial mung bean A noodles were not significant different (P ≤ 0.05). The scores for flavor and texture of canna noodles were higher than those for mung bean A noodle, but not significantly different from commercial mung bean B and C noodles, which explains the natural bland taste for canna noodles that was judged by most panelists. Sensory evaluations on the texture attribute indicated that only the Thai-purple canna noodle had a similar texture (fairly elastic, resilient, and few noodles sticking together) as mung bean noodles, whereas Thai-green and Japanese-green canna noodles had poorer quality. For the general acceptability, there were no significant differences (P ≤ 0.05) among any of the samples.

Paired-comparison test. The results of the paired-comparison test by 15 panelists are shown in Figure 4. The height of each bar indicates the percentage ratio of panelists who preferred each mung bean noodle compared with each type of canna noodle. By binomial analysis at P ≤ 0.05, the data were judged to be different if the preference for mung bean noodle was more than 73% or less than 27%. In term of color, the preferences for the canna noodles, except the Thai-purple noodle, were not significantly different from those for the commercial mung bean noodles. There were also no significant differences in the preferences of flavor among any of the samples. The preferences for texture of canna noodles, except the Japanese-green noodle, were inferior when compared with the mung bean noodle A, but were not significantly different from the commercial type of mung bean noodles.
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mung bean noodles B and C. Similarly, the panelists accepted the mung bean noodle A rather than the canna noodles, except for the Japanese-green noodle. However, the general acceptability of all canna noodles was not significantly different from mung bean noodles B and C. The superior score on texture of the mung bean noodle A was correlated with its high tensile stress (Table 1).

Conclusions

The appearance of dried canna noodles was very similar to that of commercial mung bean noodles. The canna noodles had the advantages of high clarity, bland taste, and low cooking loss. Their measured tensile stress was lower than the commercial mung bean. The most important attribute affecting the acceptability was presumably the texture of noodles that was contributed to the tensile strength. The strength of the noodles may be improved by chemical modification of the starch or by blending it with other starches.

References