*As. J. Food Ag-Ind.* **2009**, 2(04), 521-538

OPEN ACCESS

*Asian Journal of Food and Agro-Industry*

**ISSN 1906-3040**

Available online at www.ajofai.info

*Research Article*

# Protein enrichment of oriental noodles based on *Canna edulis* starch

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## Abstract

Spray drying, drum drying and extrusion cooking were applied in order to find out the best treatment for pre-gelatinisation of *Canna edulis* starch for noodle processing. Spray-drying proved to be the gentlest process to modify the native starch, whereas cooking extrusion was too drastic. Adding either native or pre-gelatinised *C. edulis* starch to wheat flour noodles increased the solids loss, whereas noodles made of *C. edulis* only, showed lower cooked weight and solids loss than commercial samples. *C. edulis* noodles with the best cooking stability were obtained by mixing 12% pre-gelatinised starch, 28% native starch and 60% water, dipping in boiling water for 60 seconds, cooling in water at room temperature (17°C) for 60 seconds and then oven drying at 17°C. Protein enrichment of *C. edulis* noodles by adding either lupin concentrate or defatted soybean flour showed that lupin-*C. edulis* and soybean-*C. edulis* mixtures had higher solids loss than noodles prepared by using *C. edulis* starch only. Sensory evaluation results showed that the cooling of noodles in water at room temperature did not make any difference to the appearance and texture compared to samples cooled down at 0°C. *C. edulis* noodles of 1.5 mm and 0.8 mm diameter showed big differences with commercial samples. Moreover, an improvement on the appearance and texture of *C. edulis* noodles was observed by reducing the noodle diameter from 1.5 to 0.8 mm. Acceptability test of the protein enriched noodles showed that consumers had preference for the mixture Lupin-*C. edulis*.

**Keywords**: noodles, pre-gelatinisation, starch, cooking stability, protein enrichment, drying, sensory evaluation, Ecuador.

**Introduction**

*Canna edulis* (arrowroot, or *Phuttaraksa* in Thai), is an ancient Andean root crop, but it is little used today in its native area [1]. The fibrous rhizome has a poor eating quality and a long cooking time, from two to five hours [2]. However, the relatively high starch content of *C. edulis* (12 to 16%) makes its extraction the main use of the root [2]. In Vietnam, for example, *C. edulis* starch is processed to obtain transparent oriental style noodles on a large scale, which constitutes a novel use of the *C. edulis* starch [3].

In traditional wheat noodle processing the presence of an elastic and compact gluten protein network prevents swelling and solubilisation of starch granules avoiding noodle stickiness and cooking losses. In starch noodles, the gluten protein network has to be replaced by a gelling agent by using the gelling properties of starch. These properties are revealed on the gelatinised starch after heat treatment [4]. Heating treatments commonly used in the production of noodles are steaming, cooking in water, extrusion cooking and drum-drying. Cooking in water is a very common method, suitable for small scale processing. However, for large scale production, dough handling becomes more difficult as well as the possibility of microbiological contamination increases [5].

The characteristics of pre-gelatinised starch are important for the quality of noodles. Pre-gelatinised starch should show high viscosity at low temperature, immediately after mixing with native starch and water, to be able to form the needed network. Pre-gelatinised starch should also have good retrogradation properties [6, 7]. Crystalline amylose networks which are built during the retrogradation have been reported to be the texturing agent, which keeps the starch noodles together avoiding the starch solubilisation in a hot aqueous medium [4, 8, 9].

*C. edulis* starch has a high peak viscosity observed during gelatinisation, a high amylose content (25-38%), and high gel retrogradation [10, 11, 12]. It is also high in phosphorus, calcium and potassium [13]. These special characteristics make the *C. edulis* starch interesting for the food industry and the utilisation of *C. edulis* could be increased with further investigation of the characteristics and the product development by finding out new applications.

Lupin (*Lupinus mutabilis*) has around 40% protein content. Mixtures of lupin with cereals can lead to obtaining a food containing the right balance of essential amino acids for the human diet. The problem with the utilization of lupin is the presence of alkaloids. However, the use of suitable aqueous alcohols like isopropanol, methanol and ethanol make it possible to obtain protein concentrates in an environmentally friendly way [14]. Lupin flour and its products might represent a useful raw material. Its use will depend upon its functional properties in order to find possible applications in food products [15]. Previous studies have shown that lupin flour can be successfully incorporated into products [16].

Soybean is a protein source. The protein content of most beans averages 20-25%, whereas the protein content of soybean is about 40% [17]. Soybean protein contains sufficient lysine, which is deficient in most cereal proteins. Therefore, soybean amino acid profile is complementary to cereal amino acid profile. Thereby, legumes may be used to fortify cereals [18].

According to the World Health Organisation the daily protein recommended intake is 33 g, which is the average for men and women with moderate physical activity [19]. Considering a noodle ration of 80 g (d.b.), noodles made from a mixture lupin-*C. edulis* have half of the protein daily intake, whereas soybean-*C. edulis* mixture has one third of the protein daily intake. In this study particular importance was given to the effects that addition of either lupin or soybean could produce on the external and textural attributes of noodles, criteria which may impact heavily on commercial noodle quality [20, 21, 22, 23, 24].

In the present research a method for small-medium scale processing of oriental style noodles based on *C. edulis* starch was developed. Additionally, protein enriched oriental noodles were processed in order to improve nutritional quality. The use of *C. edulis* starch may help to increase its utilisation in the Andean region in Ecuador.

## Materials and Methods

*C. edulis* starch was extracted according to Santacruz, *et al.* [25]. *C. edulis* rhizomes were obtained in Patate, Ecuador.

Pre-gelatinisation of the starch was performed by using three different processes: spray drying, drum drying and extrusion cooking.

The processing of noodles was performed in a cold extruder (La Parmigiana Mod. D 45/D 55N, Italy) with dies of either 1.5 mm or 0.8 mm diameter. Protein enrichment of noodles was done by using a die of 0.8 mm diameter and by adding either lupin protein concentrate or defatted soybean flour. Lupin concentrate was prepared according to Guerrero [26], whereas defatted soybean flour was obtained from the local market in Quito. Commercial noodles from Vietnam were supplied by the International Potato Centre (CIP), Quito, Ecuador and used as references for the present study.

Training and sensory evaluation utilised three commercial oriental noodles: Lungkow Vermicelli, green bean thread, Shandong Cereals and Oils Co., Qindao-China (mung bean); Tree peony brand, Tungoon, dried rice stick, (thick rice); Hsinhua, Rice Vermicelli, fine, Cereals Oils & Foodstuffs Corp., China (thin rice).

### *Chemical Analyses*

Moisture, fat, protein, total carbohydrates and ash of *C. edulis* starch were determined according to AOAC [27].

### *Spray-drying*

A spray-dryer (A/S atomiser Copenhagen, Denmark no: 1374) was operated by loading a slurry of 25% solid content at a feeding rate of 40 ml/min, incoming air temperature 240ºC, and outgoing air temperature 80ºC.

### *Extrusion cooking*

The extrusion cooking was done by using a single screw extruder (Brabender DCE 330, Germany). The feed-supply was kept at 66 g/min, the particle size of the material was between 8 to 35 mesh with a moisture content of 24%. Four temperature profiles along the barrel, 50-50-50, 80-80-80, 80-100-120, and 100-120-150ºC, together with a rotating speed of 80, 120 and 150 revolutions per minute (Table 1), and a die of 3 mm of diameter were used during the extrusion cooking.

***Drum-drying***

A drum-dryer (double drum-dryer, model 215, Mathis Machine Corp., South bend, Indiana, tool no:14017) with two rotating drums was heated at 145ºC by saturated steam. The separation between the drums and the feeding height were kept constant during all the processing with values of 1 mm and 3 cm, respectively. The starch-water relation and the rotating speed were varied during the study as follows: water:starch ratio of 1:1 and speed of 6 rpm; 1:1, 8 rpm; 1.25:1, 8 rpm and 1,5:1, 8 rpm.

**Table 1. Moisture, Swelling power (SP), Water Absorption Index (WAI) and Water Solubility Index (WSI) of native and thermally modified starches**.

| Sample | Moisture [1] | SP [1] | W.A.I. [1] | W.S.I. (%) [1] |
|---|---|---|---|---|
| Native starch | 11.0 | 1.8 | 1.8 | 1.0 |
| Extruder 80-100-120ºC, 120 rpm | 6.3 | 13.0 | 13.0 | n.d. |
| Extruder 100-120-150ºC, 120 rpm | 6.1 | 12.9 | 12.9 | n.d. |
| Extruder 80- 80-80ºC, 150 rpm | 10.2 | 12.9 | 12.9 | n.d. |
| Extruder 50-50-50ºC, 80 rpm | 11.7 | 11.7 | 9.5 | 9.2 |
| Spray dried | 10.4 | 2.2 | 2.2 | 0.5 |
| Drum dried 1.5:1, 8 rpm | 8.9 | 7.5 | 6.9 | 7.9 |
| Drum dried 1.25:1, 8 rpm | 7.4 | 9.3 | 7.1 | 4.3 |
| Drum dried 1:1, 8 rpm | 11.2 | 8.4 | 7.8 | 6.1 |
| Drum dried 1:1, 6 rpm | 11.0 | 13.1 | 13.1 | n.d. |

1: measurements made in duplicate
n.d.: not determined

***Amylograph viscosity***

Brabender amylograph viscosity was determined by using a Brabender amylograph (Visco/Amylo/Graph, Brabender OHG Duisburg, Germany) according to Ruales and Nair [28].

***Swelling power (SP), water absorption index (WAI) and water solubility index (WSI)***

SP, WAI and WSI were determined according to Anderson, *et al.* [29]. Samples (2,5 g) were suspended in 30 ml distilled water at 30ºC in centrifuge tubes, stirred for 30 min at 30ºC and afterwards centrifuged at 2500 g for 20 min. The amount of supernatant was measured and the gel weighed. WAI was calculated as the weight (g) of gel per gram of dry sample. Sample of 10 ml of supernatant was dried at 90ºC and the weight (g) of solubles was determined. WSI was defined as the weight (g) of solubles in the supernatant per gram of total matter multiplied by 100. SP was calculated as the ratio of gel weight and the difference between the weight of dry sample and weight of solubles in the supernatant (all weights are expressed in grams).

***Gelatinisation temperature***

Gelatinisation temperatures from native starch and three drum-dried samples were determined using differential scanning calorimetry (DSC) according to Ruales [30]. The milled sample was weighed in an aluminium pan and the necessary water was added with a micropipette to obtain a water-starch rate of 2:1. The pan was sealed and loaded in the oven of the DSC. The temperature increased from 20ºC to 120ºC at a scanning rate of 10ºC/min. An empty pan was used as reference.

***Cooking analysis***
Samples of 8 grams of noodles were soaked in 400 ml of distilled water for 5 minutes. Afterwards the noodles were boiled in 240 ml distilled water for 9 min in order to get an adequate texture ("al dente"). After cooking, water was extracted by vacuum filtration for 2.5 min. The cooked weight of noodles was determined as the relation between the weight of cooked and uncooked noodles. The solid loss was determined by drying at 110°C and reported in relation to the weight of uncooked noodles [9].

***Noodles processing: partial substitution of wheat flour***
Partial substitution of wheat flour was performed by using either wheat flour-native starch or wheat flour-pre-gelatinised starch (drum dried starch at water:ratio of 1:1 and 8 rpm). The maximum level of substitution of wheat flour by starch was 12%. Higher contents of pre-gelatinised starch made the cold extrusion process impossible. Water should be added to a starch-flour mixture in amounts of 60% to give the adequate texture to perform cold extrusion. The 40% left consisted of a mixture of wheat flour and starch in amounts as follows: 36 and 4, 32 and 8, 28 and 12%, respectively (Table 2). After cold extrusion, the obtained noodles were cut by hand and dried at 17°C (room temperature).

***Noodles processing: oriental noodles based on starch***
Similar noodle processing was performed for the third mixture, which consisted of native and pre-gelatinised starch in amounts of 36 and 4, 32 and 8, 28 and 12%, respectively. After cold extrusion noodles were cut by hand using a knife and collected in boiling water (boiling point in Quito, Ecuador is 91°C) for either 30 or 60 sec. Immediately after boiling, the noodles were cooled down by using either refrigeration (8°C) or cold water at either 0°C or room temperature. When refrigeration was used, noodles were kept for 1, 2, 3 or 4 h, whereas water-cooling times were 1, 30 or 60 min. The noodles were then dried at room temperature (17ºC) or in an oven at 45°C. All samples were stored in plastic bags at 4°C for further analyses. The best combination of processing parameters which resulted in noodles with the best cooking stability, highest cooked weight and lowest solid loss, were obtained by statistical evaluation with a STATGRAPHICS computer software, variance multi-factor analysis, Tukey method, with a significance level of 5%.

***Protein enrichment***
The composition of the protein enriched mixtures to be cold extruded was:

a) Soybean-*C. edulis* noodles: 12% soybean flour, 12% pre-gelatinised *C. edulis* starch, 16% native *C. edulis* starch and 60% water.
b) Lupin-*C. edulis* noodles: 10% lupin concentrate, 12% pre-gelatinised *C. edulis* starch, 18% native *C. edulis* starch and 60% water.

Soybean flour and lupin concentrate were added at the highest permissible values, 12% and 10% respectively, higher amounts do not permit the formation of noodles during the cold extrusion.

***Sensory evaluation***
**Training sessions.** A group of 12 people were trained for the sensory evaluation. Two training sessions were done well in advance of the sensory analyses being performed. During the first session the panelists chose the properties considered to be the most important for describing the external appearance and texture of noodles to be evaluated during the study. Whereas, in

the second session, the external appearance and textural properties were evaluated. Four samples with different textures were used during the first training; one dried rice stick noodle sample, one mung bean and two *C. edulis* noodle samples (noodles with 0.8 and 1.5 mm diameter). Approximately 50 grams of each sample were cooked in 1.5 l of tap water. Cooking times varied between 5 to 20 minutes in order to obtain different textures. Samples were cooled down to room temperature before being served to the panelists. On the second training session four different noodle samples were given to the panelists. Approximately 50 g of each sample was cooked in 1.5 l of tap water until "al dente" texture was obtained, which was approximately 9 min. The samples were cooled down in water at room temperature and served to the panelists.

A list of the terms considered to be the most important was obtained with the panelists and is listed as follows:
*Visual analysis:*
Colour (light/dark)
Roughness (smooth/rough)
Transparency (transparent/opal)
Agglomeration (not agglomerated/agglomerated)
*Texture:*
Hardness (soft/hard)
Chewiness (not chewy/chewy)
Elasticity (not rubbery/rubbery)
Adhesiveness (not sticky/sticky)
Mouthfeel (dry/wet)

**Sensory evaluation analyses.** Once the training sessions were concluded, the sensory evaluation was performed by using two sessions per day. A descriptive test of the samples and the reference was utilised.

A comparison between *C. edulis* noodles of two diameters, 1.5 and 0.8 mm, with commercial samples using mung bean noodles as reference, was performed. Additionally, two protein enriched samples, lupin-*C. edulis* and soybean-*C. edulis*, together with *C. edulis* noodles as reference were evaluated by the panelists. Noodles of 0.8 mm of diameter were used during the evaluation of protein-enriched noodles. Two additional parameters were included on this sensory evaluation, odour and flavour. The additional parameters were included in order to find out any change that could come from the presence of the protein of either lupin or soybean.

Samples for the sensory evaluation were prepared by weighing 150 g of noodles, which were soaked in water at room temperature for 5 min. Afterwards the noodles were cooked in 3 l of water at boiling temperature for 9 min. The noodles were cooled down by soaking in water at room temperature, before being served to the panelists.

The sensory evaluation was performed using a lineal scale from 0 to 10. The results were processed with a STATGRAPHICS at a significance level of 5%.

***Acceptability test***
The acceptability test was performed in order to find out the preference for any particular

sample over the others. The analyses were done by university students, 39 panelists in total (21 women and 18 men). *C. edulis*, soybean-*C. edulis*, and lupin-*C. edulis* noodles with a diameter of 0.8 mm were used in the analyses.

Noodles were prepared by cooking in tap water for 9 min. Samples were served warm together with soybean and hot chilli pepper sauces. However the flavour of the noodles had to be evaluated without the sauce.

A hedonic scale of 7 was used to evaluate appearance, texture, flavour and the score of each sample. Additionally, the panelists were asked about their intention of buying the samples.

## Results and Discussion

### *Chemical Analyses*

The quantities of fat, protein, total carbohydrates and ash of *C. edulis* native starch were 0.1, 0, 92.2 and 0.4%, respectively, being similar to the values reported by Santacruz, [31]. The protein content of lupin concentrate and defatted soybean flour were 79.0 and 46.8%, respectively, whereas the protein content of lupin-*C. edulis* and soybean-*C. edulis* noodles were 16.5 and 11.0%, respectively.

### *Temperature of gelatinisation*

The onset and ending temperatures, together with the enthalpy of gelatinisation of *C. edulis* starch were 58.9, 73.7ºC and 23.1 J/g (d.b.), respectively, which are similar to what has been reported in the literature [32]. DSC analyses of the drum-dried samples showed no endotherm peak of gelatinisation (data not shown), leading to the assumption of complete gelatinisation during the drum-drying process.

### *Swelling power (SP), water absorption index (WAI) and water solubility index (WSI)*

SP, WAI and WSI of native and spray-dried starches did not differ from each other and were lower than starches prepared by extrusion cooking and drum drying (Table 1). The extruded samples had the highest SP, WAI and WSI, followed by the drum dried starches.

### *Amylograph viscosity of native, extruded, spray-dried and drum-dried starches*

Amylograph viscosity showed that spray-drying was the less drastic among the three processes, producing a starch which has similar amylograph viscosity to the native starch. On the other hand, amylograph viscosity obtained from extruded starch showed a low and constant viscosity along the heating-cooling profile (Fig 1). This could indicate that under extrusion cooking conditions, the temperature and the shear stress applied during this process caused high molecular degradation. Drum-dried starch showed a high viscosity at cold temperature, which decreased with the increment of temperature. The setback in the cooling stage was negligible for both, drum-dried and extruded starches (Fig 1).

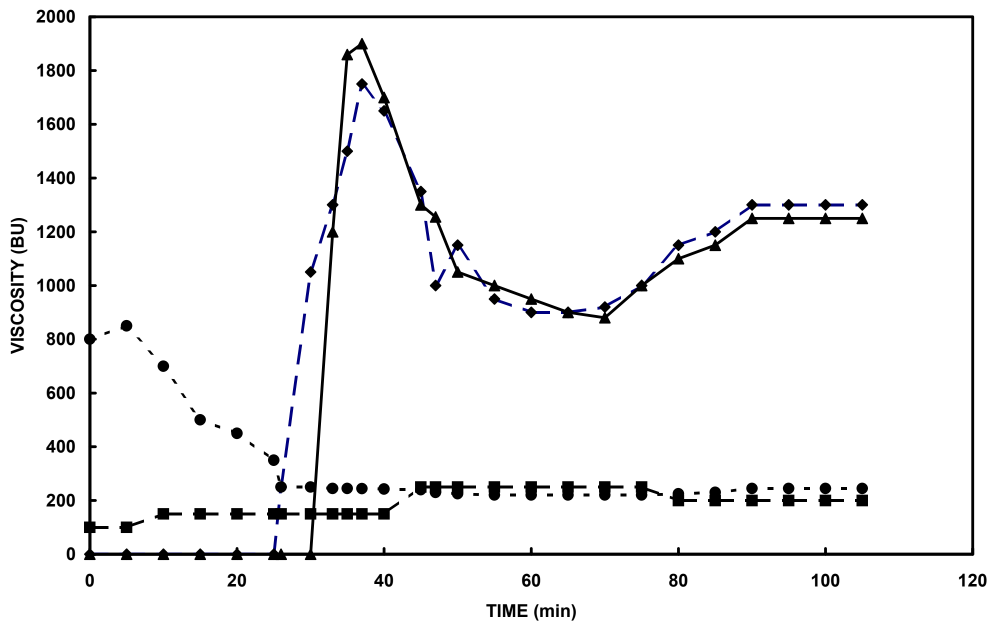


**Figure 1. Amylographs of native and pre-gelatinised starches.**
Spray-dried ♦, extruded ■, native ▲, drum-dried •

The high viscosity of the drum-dried starch at low temperature lead to choosing this thermal modification for further improvements. An increment of the setback, higher retrogradation, was achieved by trying out different drum-drying parameters with different rotating speeds and water-starch ratios (Fig 2). Drum-dried sample prepared with a water:starch ratio of 1:1, and 6 rpm was jelly-like, showing low initial viscosity and high setback. The sample at water-starch ratio of 1:1 and at 8 rpm showed high initial viscosity, but no setback behaviour. A jelly like product with moderate initial viscosity but without setback was obtained by drum-drying with a water:starch ratio of 1.5:1 and 8 rpm. The sample at 1.25:1 water:starch ratio and 8 rpm, showed a high initial viscosity and slight setback. Drum dried starch at water:ratio of 1:1 and 8 rpm was chosen as the pre-gelatinisation method for noodle preparation due to its high viscosity at low temperature, immediately after mixing with native starch and water, to be able to form the needed structure that replaces gluten in noodle formation. Pre-gelatinised starch should also have good retrogradation properties [6].

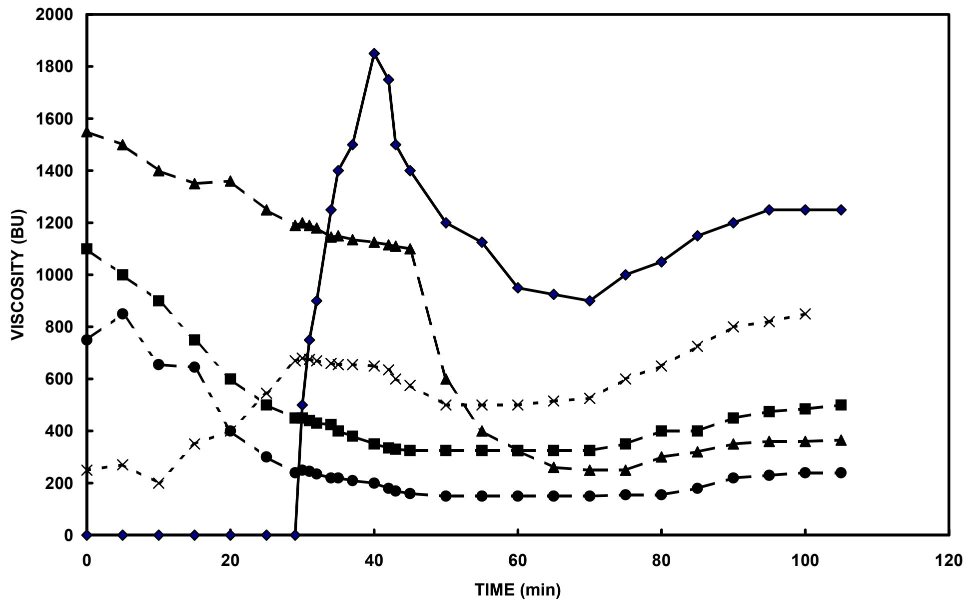


**Figure 2. Amylographs of native and drum dried starches with different water:starch ratios.**

Native ♦, drum-dried 1:1 and 6 rpm x, drum-dried 1.25:1 and 8 rpm ■, drum-dried 1:1 and 8 rpm ▲, drum-dried 1.5:1 and 8 rpm •

***Noodles processing: utilisation of three mixtures, native C. edulis starch-wheat flour, pre-gelatinised C. edulis starch-wheat flour and native-pre-gelatinised C. edulis starch***

Noodles were processed by partial replacement of wheat flour with native or pre-gelatinised starch (Table 2). The amounts of wheat flour that were replaced were 4, 8 and 12%. The increase of native starch content in wheat flour noodle composition increased cooked weight, whereas an increment of pre-gelatinised *C. edulis* starch showed a reduction of the cooked weight with no significant difference. The solid loss results did not follow a special trend, however noodles made with mixtures of wheat flour and either native or pre-gelatinised starch had higher solid loss than wheat flour noodles. This shows that there is no improvement on the cooking stability (cooked weight and solid loss) of wheat flour noodles by adding either native or pre-gelatinised *C. edulis* starch.

Regarding noodles made with either native or pre-gelatinised starch, statistical analyses revealed the necessary processing parameters which result in noodles with the best cooking stability, highest cooked weight and lowest solid loss. Highest cooked weight was obtained by processing a mixture of 12% pre-gelatinised starch, 28% native starch and 60% water; steeping in boiling water for 60 seconds; cooling in water at either 0°C or room temperature (no significant difference was found for the different cooling times); and drying in an oven at 45°C. The lowest solid loss was obtained for a mixture of 12% pre-gelatinised starch, 28% native starch and 60% water; no significant difference was found for soaking times in boiling water, cooling times, cooling temperatures and drying temperatures. Therefore, the optimal parameters to obtain noodles with the best cooking stability were: a mixture of 12% pre-gelatinised starch, 28% native starch and 60% water; soaking in boiling water for 60 seconds; cooling in water at room temperature for 60 sec and drying at room temperature (Fig. 3).

**Table 2. Cooked weight and solid losses of noodles prepared with mixtures of native *C. edulis* starch-wheat flour and pre-gelatinised *C. edulis* starch (drum dried starch at water:ratio of 1:1 and 8 rpm ) -wheat flour**

| | Cooked weight [1,2] | Solid loss (%)[2] |
|---|---|---|
| 40% wheat flour<br>60% water | 2.0 | 4.7 |
| 4% native starch<br>36% wheat flour<br>60% water | 2.1 | 6.9 |
| 8% native starch<br>32% wheat flour<br>60% water | 2.2 | 4.4 |
| 12% native starch<br>28% wheat flour<br>60% water | 2.3 | 5.8 |
| 4% pre-gelatinised starch<br>36% wheat flour<br>60% water | 2.0 | 6.4 |
| 8% pre-gelatinised starch<br>32% wheat flour<br>60% water | 1.9 | 6.2 |
| 12% pre-gelatinised starch<br>28% wheat flour<br>60% water | 1.9 | 7.9 |

1: cooked noodle weight/uncooked noodle weight
2: measures made in duplicate

The highest concentration of pre-gelatinised starch, 12%, might behave as the best one during cooking due to a major leaching and further retrogradation of the amylose fraction, originating from the pre-gelatinised starch. The highest cooked weight of 12% pre-gelatinised starch noodles is explained by the fact that starch absorbs a higher quantity of water than native starch. Cooking the noodles straight after cold extrusion permits an increase in the degree of gelatinisation of the starch leading to a major leaching of amylose fraction from the starch granule. The retrograded amylose obtained during the cooling of noodles forms a network [4, 8, 9, 33, 34], which avoids the dispersion of starch components from the noodles to the water during the cooking. It seems than the retrogradation of amylose is mainly influenced by the rapid change of temperature, being performed in a few seconds, which is explained by the fact that there was no difference for the different cooling times.

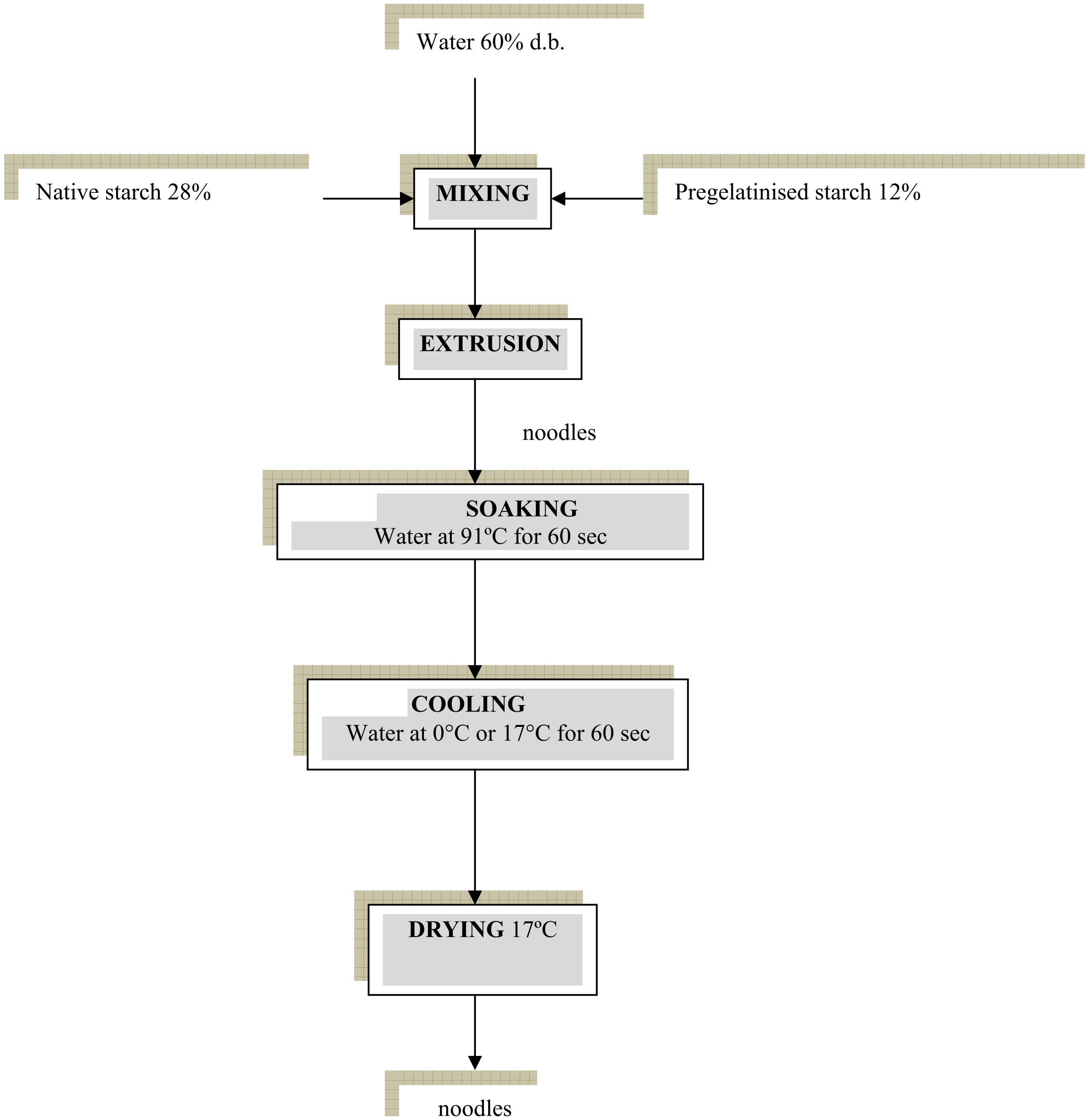


**Figure 3. Optimal parameters for noodles processing by using *C. edulis* starch.**

***Noodle processing: effect of heating-cooling treatments***

The effect of heating-cooling treatments was evaluated with the comparison of two noodle samples, one corresponding to a sample obtained with the full noodle processing and the other sample obtained just after cold extrusion. The cooking treatment after the cold extrusion permits the dispersion of the amylose, which forms a network during the cooling treatment as a result of retrogradation. Such network may avoid the dispersion of the starch components during the cooking of noodles, therefore, reducing the solid loss from 14% to 2.5%, as is shown in Table 3.

**Table 3. Cooked weight and solid loss of noodles obtained after complete processing and only after cold extrusion. Mixture of native and 12% *C. edulis* pre-gelatinised starch.**

| Processing | Cooked weight [1,2] | Solid loss (%)[2] |
|---|---|---|
| Cold extruded [3] | 3.4 | 14.0 |
| Full processing [4] | 3.8 | 2.5 |

1: cooked weight of noodles/raw noodles
2: measures made in duplicate
3: noodles taken just after cold extrusion, without cooking-cooling treatments
4: noodles obtained by a full process

Noodles made of a mixture of native starch and 12% *C. edulis* pre-gelatinised starch were compared with commercial *C. edulis* starch noodles originating from Vietnam. Commercial samples showed higher cooked weight and solid loss than the produced noodles, Table 4.

**Table 4. Comparison of cooked weight and solid loss of noodles made of a mixture of native and pre-gelatinised starch with commercial samples from Vietnam.**

| Noodles | Cooked weight[1] | Solid loss (%)[1] |
|---|---|---|
| Commercial samples [2] | 4.8 | 5.8 |
| *C. edulis* [3] | 3.8 | 2.5 |

1: measures made at least in duplicate
2: Noodle samples from Vietnam.
3: mixture of native starch and 12% *C. edulis* pre-gelatinised starch

***Improvement of the quality of oriental noodles***

The improvement of the quality of *C. edulis* oriental noodles was made by using a die with a lower diameter to produce thinner noodles. Thinner *C. edulis* noodles, 0.8 mm diameter, had a higher cooked weight and a lower solid loss than noodles of 1.5 mm diameter, Table 5. The low solid loss of thinner *C. edulis* noodles showed the improvement on the cooking behaviour.

**Table 5. Cooked weight and solid loss of noodles of two different diameters, both containing *C. edulis* pre-gelatinised and native starch together with protein fortified noodles.**

| Noodles | Cooked weight[1] | Solid loss (%)[1] |
|---|---|---|
| 1.5 mm diameter[2] | 3.8 | 2.5 |
| 0.8 mm diameter[3] | 5.5 | 0.6 |
| Lupin-C. edulis noodles [4] | 6.5 | 3.2 |
| Soy bean-C. edulis noodles [4] | 6.1 | 4.7 |
| Wheat flour noodles [4] | 4.4 | 14 |

1: measures made in duplicate
2: C. edulis starch noodles of 1.5mm diameter
3: C. edulis starch noodles of 0.8mm diameter
4: noodles of 0.8 mm diameter

***Protein enrichment***

The protein content of lupin-*C. edulis* and soybean-*C. edulis* noodles was 16.5 and 11%, respectively. Mixtures of lupin-*C. edulis* and soybean-*C. edulis* noodles had higher cooked weight and solid loss than noodles prepared by using only *C. edulis* starch (Table 5). However, the solid losses of the mixtures were lower than those of noodles prepared with wheat flour only.

***Sensory evaluation***

*C. edulis* noodles cooled at 0°C were lighter, rougher, more transparent and less agglomerated than *C. edulis* noodles cooled down at 17°C (room temperature). However there was no statistical difference.

*C. edulis* noodles cooled down at 0°C were softer, less chewy, less rubbery, less sticky and had a wet mouth-feel compared to *C. edulis* noodles cooled down at 17°C. There was, however, no statistical difference. The previous results lead to the conclusion that the cooling step of the noodle processing can be done at room temperature since there is no improvement in the appearance and texture of noodles cooled down at lower temperature (0°C). Thick and thin *C. edulis* noodles (1.5 and 0.8 mm diameter, respectively) were darker, rougher and more transparent than the commercial samples (Fig. 4).

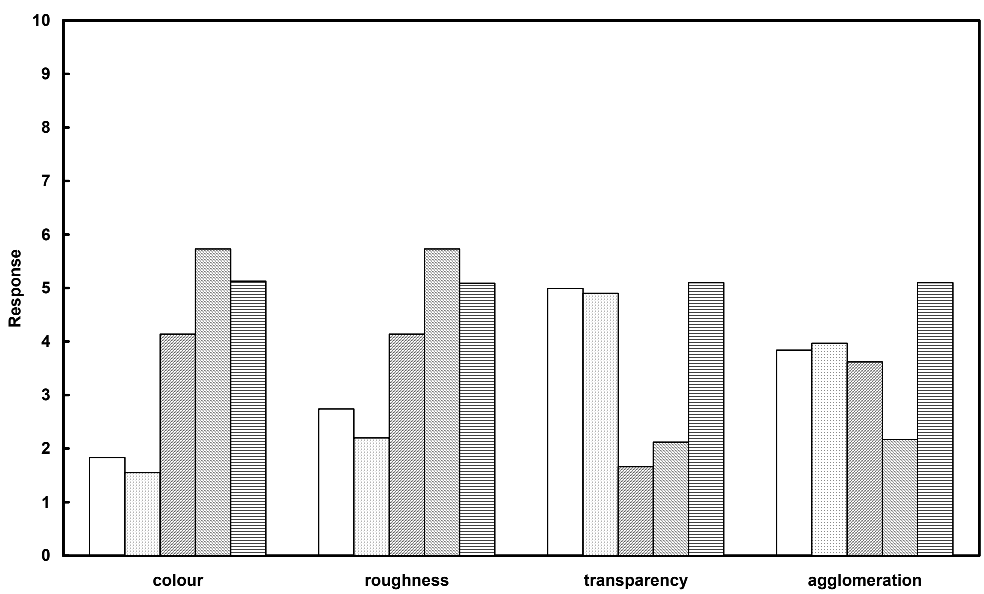


**Figure 4. Sensory evaluation: visual comparison of *C. edulis* noodles with commercial samples.**

Extremes on the y axis correspond to: colour, 0 - dark to 10 - light; roughness, 0 - rough to 10 - smooth; transparency, 0 - opal to 10 - transparent; agglomeration, 0 - agglomerated to 10 - no agglomerated. Thin C. edulis, ∴thick C. edulis, // thick rice, \\ thin rice, = mung bean.

Thin rice was the most agglomerated and mung bean was shown to be the least agglomerated one, whereas thick and thin *C. edulis* were in between. Thick and thin *C. edulis* noodles were harder than the other samples (Fig 5).

Thick and thin *C. edulis* noodles were similar in chewiness to the reference. Thick rice noodle showed to be the least chewy. Thick and thin *C. edulis* noodles were more rubbery than the other samples. There was no difference in adhesiveness among the samples. Thick rice, thick and thin *C. edulis* had a drier mouthfeel than the rest of the samples. A slight improvement in the appearance and texture of *C. edulis* noodles was found by reducing the diameter from 1.5 to 0.8 mm.

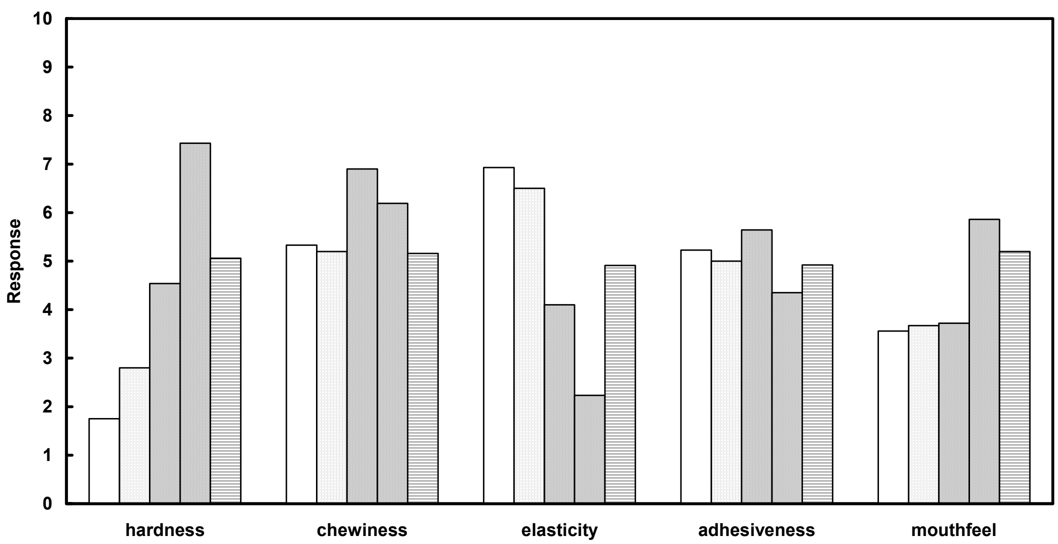


**Figure 5. Sensory evaluation: texture analysis of *C. edulis* noodles and commercial samples.**
Extremes on the y axis correspond to: hardness, 0 - hard to 10 - soft; chewiness, 0 - chewy to 10 – no chewy; elasticity, 0 – no rubbery to 10 - rubbery; adhesiveness, 0 - sticky to 10 - no sticky; mouthfeel, 0 - dry mouthfeel to 10 – wet mouthfeel. Thin C. edulis, ∴thick C. edulis, // thick rice, \\ thin rice, = mung bean.

Protein enriched noodles showed that samples containing *C. edulis* smelled different to lupin and soybean, which were similar (Fig 6). Soybean noodles were darker than the others, which were similar. There was no difference in roughness among samples. Thin C. *edulis* and soybean noodles were more opaque compared to lupin noodles. Thin *C. edulis* noodles were the less agglomerated and lupin noodles showed the maximum agglomeration. Lupin noodles had different flavour compared to the other samples, whereas soybean was similar to *C. edulis* (data not shown). Lupin and soybean noodles were softer, less rubbery and easier to chew than *C. edulis.* There was no difference in adhesiveness and mouth-feel among the samples.

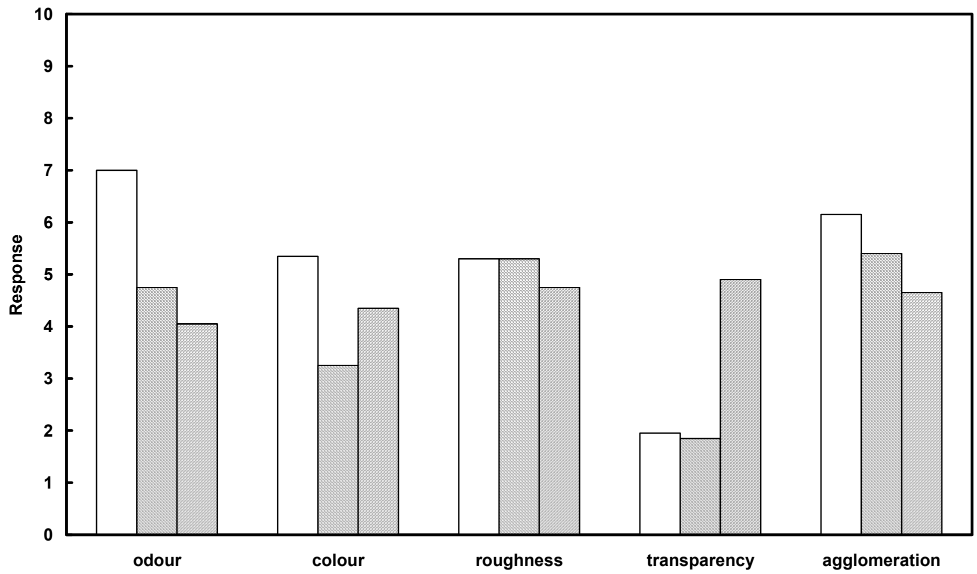


**Figure 6. Sensory evaluation: odour and visual comparison of *C. edulis* noodles with soy bean – *C. edulis* and lupin – *C. edulis* mixtures.**

Extremes on the y axis correspond to: odour, 0 – more odour to 10 – less odour; colour, 0 - dark to 10 - light; roughness, 0 - rough to 10 - smooth; transparency, 0 - opaque to 10 - transparent; agglomeration, 0 - agglomerated to 10 - not agglomerated. *C. edulis*, \\ soy bean – *C. edulis* and // lupin – *C. edulis* mixtures.

Consumers did not like the transparency of *C. edulis* noodles. The reason could be that the Ecuadorian people are used to eating wheat flour noodles, which are more opaque. Lupin-*C. edulis* noodles are similar in opaqueness to wheat flour noodles and were more accepted than *C. edulis* noodles. Soybean-*C.edulis* noodles were the less accepted by the consumers (Table 6). The intention of buying showed that from 39 possible consumers, 43.6% were willing to buy lupin-*C. edulis*, 43.6% *C. edulis* and 12.8% soybean-*C.edulis*.

**Table 6. Appearance, texture, flavour and total score of acceptability results of noodles with protein enrichment.**

| | **Lupin-*C.edulis*** | **Soybean-*C. edulis*** | ***C. edulis*** |
|---|---|---|---|
| Appearance | 5 | 2 | 3 |
| Texture | 5 | 3 | 4 |
| Flavour | 4 | 2 | 3 |
| Score | 5 | 2 | 3 |

n = 39

5: I like it
4: I like it a little bit
3: I do not like and I do not dislike it
2: I dislike it a little bit
1. I dislike it

## Conclusions

The present investigation shows the possibility of using local crops, i.e. *C. edulis* and lupin, for the processing of oriental style noodles on a small to medium scale. Drum drying was shown to be the best method to pre-gelatinize the starch for further noodle processing. *C. edulis* starch noodles with the best cooking stability were obtained by mixing 12% pre-gelatinised starch, 28% native starch and 60% water, dipping in boiling water for 60 seconds, cooling in water at room temperature for 60 seconds and drying in an oven at room temperature. Oriental style noodles with a good acceptability among Ecuadorian consumers can be produced by using a mixture of *C. edulis* starch and lupin flour. Moreover, addition of lupin flour in the processing of noodles increased both nutritional value and acceptability among consumers.

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