*Food and Nutrition Sciences*, 2014, 5, 264-270
Published Online January 2014 (http://www.scirp.org/journal/fns)
http://dx.doi.org/10.4236/fns.2014.53033

Scientific Research

# Chemical, Starch Digestibility and Sensory Characteristics of Durum Wheat/Unripe Whole Banana Flour Blends for Spaghetti Formulation

**Perla Osorio-Díaz[1*], José J. Islas-Hernández[1], Edith Agama-Acevedo[1], Sandra L. Rodríguez-Ambriz[1], María E. Sánchez-Pardo[2], Luis A. Bello-Pérez[1]**

[1]Center for Development of Biotic Products, National Polytechnique Institute, Yautepec, México; [2]National School of Biological Sciences, National Polytechnique Institute, México, D.F., México.
Email: *posorio@ipn.mx

Received August 22nd, 2013; revised September 22nd, 2013; accepted September 30th, 2013



## ABSTRACT

**Excess weight and obesity are serious public health problems, which should be addressed through encouraging the consumption of foods with high amount of low digestible carbohydrates. The objective of this study was to put together spaghetti that blends unripe banana whole flour (UBWF) and durum wheat of different levels and to evaluate their chemical composition, starch digestibility and sensory characteristics. Spaghetti with 15%, 30%, and 45% of UBWF and a control spaghetti (100% durum wheat flour) were put together. The protein content decreased (10.42% to 7.74%) as the UBWF level was increased in the composite, while the amount of ash (0.87% to 1.54%) and total starch (70.24% to 73.71%) increased. Spaghetti with 15% and 45% of UBWF had similar available starch content. The addition of UBWF increased the resistant starch content from 1.98% to 10.91%, and consequently the indigestible starch fraction (14.00% to 27.29%). Spaghetti with 30% of UBWF had good consumer acceptability and was ranked higher than the control sample.**

## KEYWORDS

**Starch; Digestibility; Banana; Spaghetti; Indigestible Fractio**

## 1. Introduction

Excess weight and obesity are serious public health problems in Mexico [1]. The consumption of foods with high indigestible carbohydrate content is an alternative way to control weight and obesity problems because these foods have a low caloric content. Pasta is a very popular food, mainly because of its low lipid (no cholesterol) and sodium content, and slow digestion [2,3]. Pasta is traditionally put together with durum wheat flour (semolina) and water. Pasta is also commercially available with added food ingredients such as egg, spinach, tomato, herbs, tuber flours, and chocolate [4]. These ingredients give color and flavor to pasta, but they do not have an important nutritional effect [5]. Several studies have reported the addition of some food ingredients to pasta for the production of functional foods. Some examples are pasta with added legume flours, amaranth, lupinus, carrot, maize, cassava starch, or banana starch [6-8], and more recently the preparation of fiber-enriched pasta using different ingredients blended with wheat flour [9,10]. In order to add commercial value to the banana fruit, banana starch has been used in pasta as a functional ingredient due to its high resistance to digestion [11,12]. Unripe banana flour (UBF) prepared from the pulp has a high level of indigestible polysaccharides, dietary fiber and antioxidant compounds [13]. UBF has been used in bread [14] and spaghetti [15]; these products presented high indigestible carbohydrate content. The peel represents around 25% - 30% of the weight (wet basis) of the banana fruit and when UBF is produced, a large amount of peel is

*Corresponding author.

discarded, representing in some cases a significant environmental problem. On the other hand, whole banana fruit has been used to produce a fiber-enriched ingredient after acid treatment [16]. Whole banana fruit can be ground into flour (WBWF), which can potentially be used as an ingredient that has a high level of dietary fiber. We hypothesize that it is possible to produce and use UBWF as a functional ingredient to blend with durum wheat in the production of spaghetti without compromising the nutritional, cooking quality, and sensory features. Additionally, the integral use of banana fruit could be an economical and ecological alternative compared with the use of UBF. The aim of this study was to elaborate and evaluate the chemical composition, texture, carbohydrate digestibility and sensory evaluation of spaghetti containing different levels of UBWF.

## 2. Materials and Methods

### 2.1. Unripe Banana Whole Flour (UBWF) Preparation

Commercial unripe (green) banana (*Musa paradisiaca* L.) fruits were purchased from the local market in Cuautla, Morelos State, Mexico. Fruits were cleaned and brushed, the ends were removed; fruits were cut into 1-cm slices and were immediately rinsed in citric acid solution (0.3% w/v). The slices were dried at 50˚C in an oven (Biotecnica del Bajio, Celaya, Guanajuato, Mexico), ground on a commercial grinder (Mapisa Internacional S.A de C.V., México, D.F.) to pass a US 50 sieve (0.3 mm), and stored at 25˚C in sealed plastic containers for further analyses.

### 2.2. Spaghetti Processing

Formulations consisting of 100% durum wheat semolina (control) and mixtures of semolina:UBWF of 85:15, 70:30 and 55:45 were prepared for spaghetti processing. The homogenized blend was mixed with water (50 mL of water for 100 g of flour) for 5 min to allow hydration. The dough was obtained, and extruded as spaghetti (1.5-mm dia) using a commercial shop sized pasta maker (KitchenAid, Model KPRA, St. Joseph, MI. USA). The spaghettis were cut as they came out of the pasta roller and dried at 45˚C for 4 h in a forced air oven. Spaghetti was prepared in duplicate for each formulation. Spaghettis (3 g) were cooked in boiling water (100 mL) until the white color in the pasta's central core disappeared, as evaluated after squeezing the spaghetti between two glass slides (66-50) [17]. Cooked spaghetti was frozen in liquid nitrogen, freeze dried, and ground to pass a 300 μm sieve, using a commercial grinder (Mapisa Internacional S.A. de C.V., México, D.F.). The samples were stored at room temperature in sealed plastic containers for further analyses.

### 2.3. Chemical Analysis

Moisture content was determined by gravimetric heating (130˚C ± 2˚C for 2 h) using 2 - 3 g raw spaghetti sample. Ash, protein (N × 5.85) and fat were assessed according to AACC methods 08-01, 46-13 and 30-25, respectively [17]. All analyses were performed in triplicate.

### 2.4. Determination of Cooking Properties

#### 2.4.1. Cooking Loss

Cooking water collected from each sample was evaporated until constant weight in an air oven at 105˚C. The residue was weighted and reported as percentage of original spaghetti sample according to approved methods (66-50 cooking loss) [17].

#### 2.4.2. Cooking Yield

Spaghetti strands (12.5 g) were cut into 5-cm long pieces, cooked in 200 mL boiling distilled water until their optimal cooking time was reached. Afterwards, they were drained and rinsed with 50 mL of distilled water at room temperature for 1 min. The samples were weighed after reaching room temperature. Water absorption was determined as [(weight of cooked drained pasta − weight of raw pasta)/weight of raw pasta] × 100.

### 2.5. Cooked Spaghetti Textural Analysis

Two batches of cooked pasta were prepared for each product. In each case, four sub-samples were evaluated by Texture Profile Analysis (TPA) using the Texture Analyzer (Stable Micro System, Godalming, UK) within 5 min after cooking. Different texture analyses were performed: spaghetti hardness, adhesiveness, cohesiveness, elasticity (or tensile strength), stickiness, and chewiness. For all measurements, the TA-XT2i was equipped with a 25-kg load cell. All samples were prepared and stored at room temperature until measurement, according to the approved AACC method (66-50 pasta cooking quality-firmness test) [17].

### 2.6. Starch Digestibility Tests

Total starch (TS) was determined by the Goñi's method [18]. Resistant starch (RS) was measured by Goñi *et al*. method [18]. In brief, protein and digestible starch were removal with pepsin (P7012 (2500 - 3500 units/mg protein, Sigma Chemical Co., St. Louis, MO) incubation (40˚C, pH 1.5, 1 h) and α-amylase (A3176 (10 - 30 units/mg solid, Sigma Chemical Co., St. Louis, MO) incubation (37˚C, pH 6.9, 16 h). The residue was treated with 2 *M* KOH and after the sample was incubated with amyloglucosidase (A-7255 (5000 units/g solid, Sigma Chemical Co., St. Louis, MO) (60˚C, pH 4.75, 45 min).

Glucose was determined using glucose oxidase/peroxidase assay (Elitech Glucose PAP SL). RS was calculated as glucose (mg) × 0.9.

Digestible starch was calculated by difference between TS and RS.

### 2.7. Indigestible Fraction

Soluble (SIF) and insoluble (IIF) indigestible fractions were assessed using Saura-Calixto's method [19]. In brief, 300 mg of sample was added 0.2 mL of a pepsin solution containing 300 mg of pepsin/mL of HCl-KCl (0.05 *M* HCl and 0.03 *M* KCl, respectively) buffer, pH 1.5. Samples were incubated for 1 h at 40˚C in a water bath with constant shaking. Then, 9 mL of Tris-maleate buffer (0.1 *M*, pH 6.9) was added and the pH checked. α-amylase 1 mL of a 120 mg/mL solution in Tris-maleate buffer was added, and the samples were incubated in a water bath at 37˚C for 16 h with constant shaking. Samples were centrifuged (15 min, 3000 *g*) and supernatants removed. Residues were washed twice with 10 mL of distilled water and all supernatants combined. The residues were dried overnight at 105˚C and quantified gravimetrically as the IIF. Supernatants were transferred into dialysis tubes (12,000 - 14,000 MWCO; Dialysis Tubing Visking, Medicell International Ltd., London, U.K.), and dialyzed against water for 48 h at 25˚C (water flow 7 L/h). Dialisates were then hydrolyzed with 1 *M* sulfuric acid at 100˚C for 90 min, and the SIF was measured with dinitrosalicylic acid [20].

### 2.8. Preference Test

For preference assessment, spaghettis were served hot on coded plates. Consumers were asked to assess their degree of liking by paper ballot using the ranking preference test on a 9-point hedonic rating scale, where 9 = like extremely and 1 = dislike extremely.

Fifty consumers were briefed on evaluation protocol and then proceed to randomly evaluate the coded samples. A total of 50 Mexican consumers (33 female, 17 male, age range 17 - 57 years) of spaghetti were sampled from CEPROBI-IPN personnel, students and visitors. Consumers were randomly approached and after obtaining demographic details, they were asked to perform the tasting and express their liking by using a hedonic scale (**Table 1**).

The stimuli were placed on separate plastic trays and labeled with three digit random numbers. The order of presentation of the stimuli was counterbalanced over consumers. Each consumer tasted approximately 1 g of each sample. Rinses were taken before tasting and swallowing the samples. Consumers responded by filling in a response sheet.

**Table 1. Nine-point hedonic scale[a] used in the preference test, with the corresponding Spanish translation.**

| English | Spanish |
|---|---|
| Like extremely | Gusta muchisimo |
| Like very much | Gusta mucho |
| Like moderately | Gusta moderadamente |
| Like slightly | Gusta poco |
| Neither like nor dislike | Ni gusta ni disgusta |
| Dislike slightly | Disgusta poco |
| Dislike moderately | Disgusta moderadamente |
| Dislike very much | Disgusta mucho |

[a]Hedonic scale: 1 = dislike extremely, 5 = neither like nor dislike, 9 = like extremely.

### 2.9. Statistical Analysis

Results are presented as mean ± SEM (standard error of mean) of three separate determinations. A commercial software programme (Sigma Stat ver. 2.03, Jandel Corporation, San Rafael, CA) was used to evaluate by one-way analysis of variance (ANOVA) to identify significant differences in the means of measured parameters. Statistically significant differences ($P < 0.05$) among means were evaluated using the Tukey multiple comparison procedure.

## 3. Results and Discussion

### 3.1. Chemical Composition

The chemical compositions of the composite spaghettis of unripe banana whole flour (UBWF) and durum wheat, along with the control sample, are shown in **Table 2**. The protein content in the composite spaghetti decreased as the level of the UBWF flour was increased in the blend. However, no statistical difference ($P < 0.05$) in the protein content was found between the control sample and the spaghetti with 15% of UBWF. This pattern is related to the effect of dilution because the pulp of unripe banana flour (UBF) [15] as well as that prepared with the whole fruit [16] has a low protein content. Composite spaghettis with UBWF presented a lower protein content than spaghettis with UBF [15] because in the former a higher amount of non-starch polysaccharides is present as a result of the peel. Spaghetti with added banana starch showed a similar pattern because the composites with 5% and 20% of banana starch had 10.6% and 9.0% of protein content, respectively [8]. The ash content increased as the amount of UBWF was increased in the spaghetti. This effect was due to the higher ash content in the UBWF than in the durum wheat. A similar pattern was reported in spaghetti with 15% of UBF (1.43%) and spaghetti with 45% of UBF (1.83%) [15]. However, the composite spaghetti with UBWF had a lower ash content

**Table 2. Chemical composition of spaghetti with unripe banana whole flour (g/100g).**

| Sample | Protein | Lipids | Ash | Total Starch |
|---|---|---|---|---|
| Control | 10.42 ± 0.90[a] | 0.54 ± 0.15[a] | 0.87 ± 0.04[d] | 70.24 ± 2.36[b] |
| 15% | 10.00 ± 0.45[a] | 0.53 ± 0.16[a] | 0.98 ± 0.06[c] | 71.44 ± 1.84[a,b] |
| 30% | 8.87 ± 0.25[b] | 0.48 ± 0.10[a] | 1.30 ± 0.03[b] | 71.34 ± 2.60[b] |
| 45% | 7.74 ± 0.32[c] | 0.40 ± 0.15[a] | 1.64 ± 0.04[a] | 73.71 ± 0.79[a] |

[a]Values is mean ± SEM. Different letters in a column indicate significant difference (P < 0.05, Tukey's test).

**Table 3. Determination of cooking properties of spaghetti with unripe banana whole flour.**

| Sample | Cooking time (min) | Cooking loss (%) | Cooking yield (%) |
|---|---|---|---|
| Control | 8.5 ± 0.19[a] | 4.94 ± 0.37[b] | 274.1 ± 1.58[a] |
| 15% | 6.0 ± 0.11[b] | 5.23 ± 0.50[b] | 269.8 ± 3.50[a] |
| 30 % | 5.1 ± 0.12[c] | 5.51 ± 0.48[a,b] | 257.1 ± 2.50[b] |
| 45% | 4.0 ± 0.15[d] | 6.42 ± 0.60[a] | 248.0 ± 2.90[c] |

[a]Values is mean ± SEM. Different letters in a column indicate significant difference (P < 0.05).

than its counterpart with UBF (**Table 2**). The fat content in the spaghetti did not change with the addition of UBWF; this pattern is in agreement with the fat content in spaghetti with UBF [15] and banana starch [8].

A slight increase, but significant (P < 0.05), in total starch (TS) content was assessed in the spaghetti with the highest UBWF level. Similar results were reported using UBF and durum wheat flour [15]. Conversely, a higher TS level was reported in spaghetti with 100% durum wheat flour (74.1% and 73.9%) [21-23]. This pattern is due to the higher total starch content in unripe banana [15].

## 3.2. Cooking Tests

The cooking time decreased as the level of UBWF increased in the composite spaghetti (**Table 3**). The addition of non-gluten flours in the production of spaghetti dilute the gluten strength of the semolina, interrupting and weakening the overall structure of the spaghetti, facilitating the heat transfer during cooking and thus leading to faster cooking [6]. The control spaghetti as well as those with 15% and 30% of UBWF had similar cooking loss values (**Table 3**); the spaghetti with the highest UBWF level showed the highest cooking loss value. The control spaghetti had the lowest cooking loss value (4.94%), a value that was lower than in spaghetti with 100% semolina: 6.40% - 6.50% [24] and 6.50% [8]. However, the lower cooking loss value (0.93%) was determined in the spaghetti with 100% semolina [25]. These values show that wheat durum varieties and the process conditions for spaghetti preparation play an important role in the cooking loss. For spaghetti made with 100% semolina, the cooking loss of ≤8% is considered acceptable for good quality pasta [26]. In this sense, the spaghetti types containing different levels of UBWF were within the expected values of cooking loss, and they could be considered as spaghetti of good cooking quality. A similar pattern in the cooking loss value was reported in the composite spaghetti because the control sample presented a lower cooking loss value than the composite spaghetti types. This may allow for a leaching out of more solids from the pasta into the cooking water [6]. Bahnassey & Khan [27] reported that the cooked weight of spaghetti containing navy beans, pinto beans, and lentil flours decreased compared with the control sample (100% durum wheat); however, the cooking loss and firmness of these products increased. In general, water absorption in the cooked spaghetti decreased when UBWF was increased in the composite spaghetti (**Table 3**). However, the control spaghetti and that with 15% of UBWF were not statistically different; both types of spaghetti increased 3.7 times in weight, while those with 30% and 45% of UBWF increased 3.6 and 3.5 times in weight, respectively. When UBF from the pulp was added to spaghetti, lower water absorption values were obtained; the control spaghetti increased 1.7 times in weight, while the spaghetti with the highest UBF level (45%) increased 1.5 times in weight [15].

During spaghetti cooking some soluble components go into the cooking water, reducing the amount of solids such as starch, non-starch polysaccharides, and proteins. Therefore, the water amount that can be retained in the matrix of the spaghetti is low [6]. These results are in agreement with the higher cooking loss in the formulation with higher UBWF levels.

## 3.3. Cooked Spaghetti Texture Analysis

**Table 4** shows the results of the texture analysis for the control sample and the composite spaghettis with UBWF. Texture plays an important role in determining the final acceptance by the consumer, and it is one of the predominant criteria for assessing pasta quality [28,29]. The control sample had the lowest hardness value, while no statistical difference was observed between the control spaghetti and the types with UBWF. The addition of UBWF produced an increase in the adhesiveness of the spaghetti, and this effect was higher as the level of UBWF was increased in the spaghetti. The data on adhesiveness is a measure of the force between the pasta and the contact surface [30], which is a function of the components in the spaghetti. In general, the elasticity and chewiness did not change with the addition of UBWF, although an appreciable increase in the chewiness was observed with the addition of UBWF to the blend. The addition of UBF presented similar texture values for hardness, adhesiveness, and chewiness [31], but higher values of elasticity

**Table 4. Texture attributes of cooked spaghetti with unripe banana whole flour.**

| Sample | Hardness | Adhesiveness | Elasticity | Stickiness | Chewiness |
|---|---|---|---|---|---|
| Control | 3.84 ± 0.40[a] | 1.25 ± 0.05[d] | 1.10 ± 0.05[c] | 5.25 ± 0.08[a] | 3.71 ± 0.30[b] |
| 15% | 4.15 ± 0.20[a] | 1.39 ± 0.03[c] | 1.16 ± 0.03[b,c] | 4.95 ± 0.14[b] | 6.11 ± 0.50[a] |
| 30% | 4.10 ± 0.50[a] | 1.51 ± 0.01[b] | 1.24 ± 0.06[b] | 4.53 ± 0.20[c] | 6.22 ± 0.20[a] |
| 45% | 4.05 ± 0.19[a] | 1.63 ± 0.02[a] | 1.30 ± 0.05[a] | 4.12 ± 0.11[d] | 6.58 ± 0.40[a] |

[a]Values is mean ± SEM. Different letters in a column indicate significant difference ($P < 0.05$, Tukey's test).

were obtained for the types of spaghetti with UBWF. The presence of non-starch polysaccharides in the peel could be responsible for these results.

### 3.4. Starch Digestibility

The amount of digestible starch (DS) in the spaghetti decreased significantly ($P < 0.05$) with the addition of UBWF (**Table 5**) compared with the control sample, but no difference in the DS value was found in the three composite spaghettis. A similar pattern was observed for the composite spaghettis made of a blend of UBF:durum wheat with 15% and 30% of UBF, where the DS content was similar to the control sample [15]. In another study, spaghetti with chickpea flour showed lower DS content than the control spaghetti [21].

A significant ($P < 0.05$) increase in resistant starch (RS) content was obtained in the spaghetti with the addition of UBWF, reaching 10.91% of RS content in the sample with 45% UBWF (**Table 5**). Spaghetti with 15% of UBWF presented 8.66% of RS, which represented an increase in RS level of approximately 400% compared to the control spaghetti. The spaghetti with UBWF had a higher RS content than the spaghetti with UBF at the same level of substitution. For example, the spaghetti with 15% of UBF presented 2.84% of RS content [15], and its counterpart with UBWF had an RS content of 8.66%. The difference can be explained by the UBWF including the peel. Also, more non-starch polysaccharides are present, decreasing the accessibility of the enzyme at substrate (starch). It has been reported that unripe banana flour is the natural food ingredient with the highest RS content, between 57.2% and 47.3% [11]. Another study reported that spaghetti with banana starch reached up to 10.33% of RS content in the composite, with 20% of banana starch and 80% durum wheat [8]. Additionally, noodles with banana starch at different concentrations had RS levels between 3.0% and 4.6% [32]. Nowadays, there is a growing interest in the nutritional significance of starch digestibility and dietary fiber due to the excess weight and obesity problems worldwide [33]. Therefore, the results obtained in this study on the potential use of UBWF as a food ingredient to reduce starch digestibility and increase dietary fiber (as RS) in the diet may be of importance for the food industry.

### 3.5. Indigestible Fraction

The indigestible fraction (IF) consists of those food ingredients that, being unavailable for digestion in the small intestine, pass into the colon where the fermenta- tive microflora may further process them. The soluble indigestible fraction (SIF) comprises monosaccharides, disaccharides, and oligosaccharides, while the insoluble indigestible fraction (IIF) includes RS, indigestible protein, polyphenols, and non-starch polysaccharides (cellulose, hemicelluloses and lignin) [19]. Both fractions increased as the UBWF level in the composite spaghetti were increased too (**Table 5**). A similar pattern was reported for spaghetti with chickpea flour added [21]. Another study reported that spaghetti with UBF added showed a similar pattern for the IIF (26.18% IFF at the highest UBF addition of 45%) as that observed in the present study (21.03%), but not for the SIF value [15].

### 3.6. Preference Test

**Table 6** presents the acceptability of spaghetti control and those types containing different levels of UBWF, using a 9 points hedonic scale.

The acceptability of the spaghetti containing 15% and 30% UBWF was similar, with values higher up to 6 (like slightly), indicating that there was a significant preference ($P < 0.05$) for these two samples. The acceptability for the control spaghetti (100% durum wheat flour) and that with the highest concentration of UBWF (45%) was lower than for those samples containing 15% and 30% of UBWF. An acceptability study done on spaghetti prepared with different levels of UBF demonstrated that this parameter increased with the addition of tomato flavor, and the types of spaghetti with the highest UBF content (30% and 45%) had higher acceptability than the control sample and the sample with 15% UBF [15].

## 4. Conclusion

Composite spaghetti with UBWF had a lower protein content, but a higher ash and starch content than the control sample. The cooking time was shorter and the cooking loss increased with the addition of UBWF. Some texture characteristics changed with the addition of UBWF. The resistant starch content increased when UBWF was

**Table 5. Digestible starch (DS), resistant starch (RS) and fraction indigestible (IF) of spaghetti with unripe banana whole Flour (g/100g).**

| Sample | DS | RS | IIF | SIF | TIF |
|---|---|---|---|---|---|
| Control | 68.26 ± 0.69[a] | 1.98 ± 0.02[d] | 10.95 ± 0.22[d] | 3.05 ± 0.10[d] | 14.00[d] |
| 15 % | 62.78 ± 2.12[b] | 8.66 ± 0.51[c] | 12.42 ± 0.30[c] | 3.51 ± 0.25[c] | 15.93[c] |
| 30 % | 62.59 ± 1.87[b] | 9.22 ± 0.16[b] | 17.46 ± 0.02[b] | 5.17 ± 0.21[b] | 22.63[b] |
| 45 % | 63.01 ± 1.77[b] | 10.91 ± 1.13[a] | 21.03 ± 0.91[a] | 6.26 ± 0.27[a] | 27.29[a] |

[a]Values is mean ± SEM. Different letters in a column indicate significant differences ($P < 0.05$). IIF: insoluble indigestible fraction; SIF: soluble indigestible fraction; TIF: total indigestible fraction.

**Table 6. Sensory evaluation score of spaghetti with unripe banana whole flour.**

| Sample | Score hedonic scale |
|---|---|
| Control | 5.84 ± 0.23[a] |
| 15% | 6.02 ± 0.18[b] |
| 30% | 6.06 ± 0.24[b] |
| 45% | 5.90 ± 0.23[a] |

[a]Mean ± SEM (n = 50). Mean with different letters indicate significant differences ($P < 0.05$).

increased in the blend. A similar pattern was found in the indigestible fraction; an increase of approximately 100% was determined in the spaghetti with 45% of UBWF compared with the control sample. The acceptability study demonstrated that consumers were favourable to spaghettis containing 15% and 30% UBWF. The results obtained in this study on the potential use of UBWF as a food ingredient to reduce starch digestibility and increase dietary fiber (as RS) in the diet should be important for the food industry. Additionally, the preparation of flour from whole banana fruit may be an alternative to the use of this food crop for the production of spaghetti with a high amount of indigestible carbohydrates.

## Acknowledgements

We would like to thank and acknowledge the financial support provided by SIP, COFAA, and EDI—Instituto Politécnico Nacional.

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