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ORIGINAL PAPER

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GAC ARIL AND GUM XANTHAN SUPPLEMENTATION IN WHEAT MACARONI PASTA PRODUCTION

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ABSTRACT

Background. Macaroni is a common side dish or main dish that is served with sauces. Traditional macaroni is typically made using flour, water and eggs and is typically yellow in color. It has a high amount of starch and is deficient in fiber, minerals, vitamins and bioactive components.

Material and methods. The effects of Gac aril (3, 5, 7 and 9%) and xanthan gum (1, 1.5 and 2%) on the quality characteristics of macaroni were investigated. Macaroni was evaluated for cooking quality (cooking loss, volume increase, rehydration ratio), colour, chemical (β-carotene and lycopene) and structure/microstructure to assess the impact of experimental factors.

Results. The proximate composition of Gac aril was analysed and showed that Gac aril added to macaroni recipes is a food ingredient capable of enhancing bioactive compounds (β-carotene and lycopene). Studies on the combined effects of the addition of Gac aril and xanthan gum have shown that macaroni with 7% gac and 1.5% xanthan gum used resulted in a beautifully colored macaroni product (before and after cooking), good structure, high β-carotene and lycopene content (15.26 µg/g and 61.26 µg/g, respectively). The cooking quality of the macaroni was thoroughly analyzed. The rehydration rate and volume both increased with the addition of Gac aril and the xanthan gum content increased. However, the cooking loss was shown to be slightly different. The cooking loss increased as the content of Gac aril supplement was increased, while the added xanthan gum reduced the cooking loss.

Conclusion. The effects of macaroni enrichment with gac and the use of xanthan gum on product quality were noted. The physicochemical components, bioactive compounds, firmness, microstructure and cooking quality of the analyzed products emphasized the role of the ingredients used in the results obtained. The microstructure of the product has also been improved and ensures the desired product quality attributes. Further studies are needed in order to be applied at an industrial scale and with high consumer acceptance of this new product.

Keywords: cooking quality, physico-chemical characteristics, Gac aril, xanthan gum, macaroni pasta

INTRODUCTION

Pasta is a general term for food that is basically made from an unleavened dough of buckwheat or wheat, flour and water, while macaroni is a type of dry pasta. Macaroni is a food made from durum wheat and flour;

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they are often eaten with other foods or cooked with sauces. Traditional macaroni is usually yellow in color and is produced mainly with flour, water and eggs, so it is high in starch but low in fiber, minerals, vitamins and bioactive compounds. However, the consumption of foods fortified with nutrients and natural colors has become increasingly popular in recent years. Studies on the addition of ingredients with functional properties and natural coloring compounds to macaroni have been carried out, such as wheat germ macaroni (Pınarlı et al., 2004), macaroni prepared from grain and legumes (Alshehry et al., 2022) and different plant proteins (Kaur et al., 2013). Petitot et al. (2009) produced nutritiously enhanced spaghetti by adding high amounts (35%) of legumes to durum wheat semolina. Adding different types of vegetables and fruits during macaroni processing can be a good way to improve product quality through natural colors, enhanced phytonutrients and fiber to make the products beneficial for human health.

Given the warm tropical environment, Gac fruit (*Momordica cochinchinensis*) has grown popularly in the Mekong Delta of Vietnam. Gac is notable for its vivid orange-reddish color resulting from its rich content of β-carotene and lycopene. Gac has been shown to have antioxidant, anti-aging, anti-inflammatory, anti-ulcer and antibacterial activity (Thavamany et al., 2020). The large amounts of lycopene and β-carotene, α-tocopherol and fatty acids present in Gac aril have made this ingredient widely used in both nutritional and medicinal purposes. Vuong et al. (2002) confirmed that the β-carotene in gac fruit is highly bioavailable. Thavamany et al. (2020) found gac fruit is a highly potential and bioaccessible source of provitamin A.

Although many biological properties have been reported for gac fruit, to date gac has not been widely used and its nutritional resources have not been effectively exploited. Therefore, the use of gac in macaroni will create a new product with nutrients and bioactive substances. However, the use of Gac aril may affect the texture of macaroni, so the incorporation of hydrocolloids in processing could improve the texture of the product. Gums are widely used in starch-based products mainly to improve stability, modify texture and facilitate processing. Kaur et al. (2015) studied the effect of guar gum and xanthan gum on pasting and noodle making properties and found that the noodles prepared with gums showed significantly lower cooking loss than those prepared without the gums. Thuy et al. (2020) evaluated the noodles' quality with the effect of orange-fleshed sweet potato, semolina and xanthan gum. Nowadays, there is not much information about the use of Gac aril with support for xanthan gum in macaroni processing. The aim of this study was to develop a high nutritional value macaroni from the addition of Gac aril and the support of xanthan gum. Their effect on the cooking quality, color and texture of macaroni were determined.

MATERIALS AND METHODS

Gac puree preparation

Gac fruit is grown naturally at the College of Agriculture, Can Tho University. Gac fruit was harvested when the fruit was completely red (Thuy and Tuyen, 2013). Gac fruit is preliminarily washed, halved and separated from the gills that surround the seeds. Gac arils were pureed, frozen at –18ºC and used for the research.

Effect of Gac aril and xanthan gum content on macaroni pasta quality

Preparation of a mixture of ingredients in the macaroni recipe with a total weight of 430 g (Table 1).

Table 1. Weight of ingredients used in macaroni recipe

Wheat flour g	Semolina g	Potato starch g	Egg g	Water g	Salt g
239	6	55	65	63	2
Total weight of the mixture: 430 g					

The study was designed with 2 factors, including the ratio of Gac arils with 4 levels (3, 5, 7 and 9%) and the ratio of xanthan gum with 3 levels (1, 1.5 and 2%). These were calculated according to the total weight of the mixture (shown in Table 1). The total number of treatments was 12 and each treatment was repeated 3 times. The prepared mixture was put into a PHILIPS Macaroni Maker (Japan). The mixing time of the ingredients was set for 5 minutes and the dough was incubated for 30 minutes (Thuy et al., 2020). When the time was up, the machine was started to squeeze the macaroni. The macaroni was then cooked to boiling for 5 min, cooled and analyzed for quality.

Chemical-physical properties analysis

Chemical composition. Moisture content and lipid content of raw material and product were determined by AOAC (2005). The β-carotene content was determined according to the method of Fikselová et al. (2008). 25 g of samples were added to 100 g of 2-propanol and extracted at 60°C in a water bath and shaken. After one hour of extraction, a 5 ml sample was taken and mixed with 20 ml petroleum ether. Water was added for the separation of phases, and after the separation, the petroleum-ether-carotenoid phase was made up to the volume of 50 ml. The content of β-carotene in the petroleum-ether extract was measured at the wavelength of 450 mm using the spectrophotometer (V-5000 Visible, China) and then calculated using equa. 1.

$$\beta\text{-carotene } (\mu g/g) = \frac{A \times d \times V}{E_{1cm}^{1\%} \times w} \quad (1)$$

Where A is absorbance; d is dilution (g/ml); $E_{1cm}^{1\%}$ is absorption coefficient of β-carotene in petroleum ether (2592); w is weight of sample (g); V is total volume of extract (ml). Multiply by 100 to give the carotene content in μg/100 g.

Extraction of lycopene from the Gac aril sample was performed according to the method of Kakubari et al. (2020). The sample extract was diluted five times (for the product) or 10 times (for Gac aril) with the hexane-acetone mixture, filtered and measured for absorbance at 472 nm. The lycopene content in the sample was calculated according to the formula 2.

$$W\left(\frac{\text{mg}}{\text{kg}}\right) = \frac{A \times V \times d \times 10^4}{E \times l \times m} \quad (2)$$

where A is the absorbance of the diluted extract sample at 472 nm, V: 50 mL, d is the dilution ratio of the sample, E is the specific absorbance of lycopene in petroleum ether, l is the optical path length of the absorption cell in cm, and m = the mass of the test sample in g.

Physical properties. Macaroni texture (firmness) was measured using Rheotex (Japan). The sample was placed on the texture analyser platform and compressed with a 1 cm diameter flat bottom cylindrical probe. The vertical force applied to the specimen surface with a path length of 4 mm and a fixed speed of 1 mm/s was measured. The color of the macaroni was determined according to the L^*, a^*, b^* using a Colorimeter (Konica Minolta CR-400/CR-40, Japan). The value displayed on the instrument was read. At least five measurements were carried out on each sample.

Scanning Electron Microscopy (SEM). SEM dried macaroni was mounted onto brass stubs using double-sided carbon conductive adhesive tape. A gold coating (0.5 nanometers thick) was then applied under 8–9 pascal vacuum. Bulk samples were examined at 10 kV, the sample distance to the 7 cm ejection glass and 600× magnification using a JEOL model J550 scanning electron microscope (Japan) (Thuy et al., 2020).

Cooking quality. Cooking loss (%), weight increase (%) and volume increase (%) were measured to determine the cooking quality of macaroni. 50 g of macaroni were placed into 500 mL of boiling water. After 5 min of cooking, samples were removed, washed with distilled water and drained for 2 min. The cooked macaroni was collected and dried in an oven at 103°C for cooking loss (CL) estimation (eq. 3) (Wang and Ratnayake, 2015). The cooked macaroni was dried in the oven at 103°C for 20 h to estimate the rehydration ratio (RR) (eq. 4) (Kamolchote et al., 2010). The volume increase (%) was also estimated (eq. 5).

$$\text{CL}(\%) = \frac{\text{Weight of residue cooking water (g)}}{\text{Weight of pasta sample (g)}} \times 100 \quad (3)$$

$$\text{Rehydration rate } (\%) = \frac{\text{WCN (g)} - \text{OWN (g)}}{\text{OWN (g)}} \times 100 \quad (4)$$

where WCN is the weight of the cooked noodles and OWN is the original weight of the noodles.

$$\text{Volume increase (\%)} = \frac{\text{Volume of cooked macaroni} - \text{Volume of uncooked macaroni}}{\text{Volume of cooked macaroni}} \times 100 \quad (5)$$

RESULTS AND DISCUSSION

Proximate composition of Gac aril

Gac aril added to macaroni recipes is a food ingredient capable of enhancing nutritional value and bioactive compounds. The analysis results showed that the moisture content of Gac arilis around 75.97 ±1.26%. Similarly, Mai et al. (2013) showed that the moisture content of Gac aril is 76.8 ±3.3%. The average moisture content of Gac aril was reported to be 77% (FAO, 2007).

The β-carotene content in Gac aril ranges from 525.43 ±6.34 μg/g. This result was lower than that of Ishida et al. (2004) is 636.2–836.3 μg/g and higher than some other publications. Analytical concentrations were 60–140 μg/g, 83.3 ±40.4 μg/g and 355 μg/g as published by Aoki et al. (2002), Vuong et al. (2003) and Vuong (2000), respectively. The β-carotene content of gac variety grown in Thailand was about 260 μg/g FW (Kubola and Siriamornpun, 2011, Wihong et al., 2014). Nhung et al. (2010) reported that the β-carotene content in Gac aril was from 257 to 379 μg/g FW.

Lycopene was found to be mainly present in Gac aril with a concentration up to 2109.72 ±5.65 μg/g. Aoki et al. (2002) reported lycopene in the seed membrane as 380 μg/g. The lycopene content from gac fruit cultivated in Thailand varied from 700 μg/g to 1160 μg/g FW (Kubola and Siriamornpun, 2011; Wihong et al., 2014). However, the higher concentrations of lycopene in the gac were found (2378 to 3728 μg/g FW) by Nhung et al. (2010). These differences were mainly due to the nutritional composition of gac changes at the ripening stages (Thuy and Tuyen, 2013), genetic factors, varieties and growth environment. There is also post-harvest deterioration from transportation, storage and analytical methods used.

Table 2. Some physical-chemical properties of cooked macaroni supplemented with different concentrations of Gac aril and xanthan gum

Xanthan gum %	Gac aril %	Color			β-carotene μg/g	Lycopene μg/g	Firmness g force
		*L**	*a**	*b**			
1	3	66.38 ±0.72	12.96 ±0.62	28.89 ±1.09	6.72 ±0.45	26.97 ±1.56	134.90 ±2.06
	5	63.49 ±0.97	14.76 ±0.35	32.29 ±0.63	11.09 ±0.32	44.54 ±2.03	117.80 ±3.94
	7	60.50 ±1.15	16.58 ±0.73	35.74 ±0.85	15.39 ±0.56	61.80 ±1.87	101.80 ±4.34
	9	57.59 ±0.65	18.54 ±0.86	38.15 ±0.91	19.61 ±0.67	78.74 ±0.78	77.40 ±2.21
1.5	3	66.54 ±0.69	16.50 ±0.71	28.09 ±0.71	6.66 ±0.51	26.73 ±094	145.70 ±3.52
	5	63.85 ±0.91	14.99 ±0.37	31.99 ±1.02	11.00 ±0.34	44.15 ±1.12	132.60 ±3.87
	7	60.45 ±0.92	16.53 ±0.42	36.16 ±0.97	15.26 ±0.68	61.26 ±0.98	109.40 ±2.14
	9	58.02 ±1.09	18.56 ±0.86	38.67 ±0.87	19.44 ±0.55	84.68 ±1.65	89.80 ±1.76
2.0	3	66.22 ±1.19	13.88 ±0.51	28.37 ±1.12	6.60 ±0.43	26.50 ±1.42	155.60 ±4.11
	5	63.42 ±0.76	15.18 ±0.46	32.07 ±0.61	10.86 ±0.61	43.77 ±0.75	139.60 ±2.67
	7	60.53 ±0.51	16.51 ±0.86	35.80 ±1.10	15.13 ±0.59	60.74 ±0.89	127.20 ±1.45
	9	58.29 ±1.02	18.44 ±0.93	38.04 ±0.76	19.28 ±0.68	83.98 ±1.19	95.80 ±2.18

Notes: Data are expressed as mean ±standard deviation; the *L**, *a**, *b** of the control sample were 69.33, 0.56 and 6.98, respectively. The firmness of the control sample was 125.64 ±64 g force.

Effect of Gac aril and gum xanthan content on macaroni product quality

Color. The macaroni was made from recipes containing Gac aril and xanthan gum in different proportions, and the colors of all the samples were measured after the macaroni had been boiled for a fixed time of 5 min. Table 2 showed that the color values (L^*, a^*, b^*) of macaroni products with different percentages of Gac aril and xanthan gum, respectively. L^* values of macaroni samples with all added contents were lower than control sample (without the addition of Gac aril and xanthan gum). As the content of Gac aril added to the macaroni gradually increased, the L^* value gradually decreased and there was a significant difference between the samples. The highest L^* value (66.54 ±0.69) in Gac aril and xanthan gum sample supplemented was 3 and 1.5%, while the lowest L^* value (57.59 ±0.65) was measured in the sample with Gac aril and gum xanthan added at 9 and 1%, respectively. These results are quite similar to those reported by Chusak et al. (2020). When adding unripe and ripe gac fruit powder to pasta, the L^* value decreased compared to the control sample. Some previous studies have also shown that the color of pasta can be improved by adding some naturally occurring coloring ingredients to the recipe (Mariotti et al., 2011; Mirhosseini et al., 2015). It also can be seen that, when Gac aril was added, the macaroni had a red orange color and a^* and b^* values were higher and significantly different from the control sample. This is because the red-orange color of macaroni came from the carotenoid pigment present in gac, so when increasing the percentage of gac supplement, these values also increased. The a^* values from the measured treatments showed the lowest value (12.96 ±0.62) when the percentage of Gac aril and xanthan gum supplements were 3% and 1%, respectively, while the highest value (18.56 ±0.86) was when 9% of gac was added.

Similarly, the b^* values also increased from 28.09 ±0.71 (Gac aril and xanthan gum were 3% and 1.5%) to 38.67 ±0.87 (Gac aril and xanthan gum were 9% and 1.5%). The product had an outstanding color with an appropriate gac content supplemented with the characteristic orange color of this ingredient (Fig. 1).

These obtained results are similar to those reported by Chusak et al. (2020). When adding ripe gac powder at 5 to 15% to pasta, the values of a^*, b^* increased, compared to the control sample. Gum xanthan does not affect color (L^*, a^*, b^*) because it does not contain carotenoid compounds.

β-carotene and lycopene contents. Wheat flour usually does not contain β-carotene and lycopene compounds (Collins and Pangloli, 1997). Since β-carotene improves vitamin A deficiency and is beneficial for eye health (Krishnan et al., 2012), lycopene has been linked to health benefits ranging from heart health to protection against sunburn and some types of cancer. Therefore, adding gac fruit in macaroni processing increased the nutritional value of the product and brought health benefits to users. The analysis results showed that the cooked macaroni produced with 3 to 9% of Gac aril showed an increase in the β-carotene content levels (as shown in Table 2). The lowest β-carotene content (6.60 ±0.43 μg/g) in macaroni was with 3% added Gac arils and the highest (19.61 ±0.67 μg/g) was when 9% gac was added. Similarly, the lycopene content was significantly increased in the samples supplemented with 7 to 9% gac. The highest (84.68 ±1.65 μg/g) and lowest (26.50

a b c

Fig. 1. Macaroni products: a – sample with gac supplement 7%, b – samples supplemented with gac 7% and control samples (without gac added) and c – mixed sample with Gac aril added and control samples

±1.42 µg/g) values were measured with 9% and 3% Gac aril added, respectively. The reason is that the Gac aril contains a large amount of β-carotene (Aoki et al., 2002; Ishida et al., 2004; Tran et al., 2008). Our obtained results are consistent with the report of Chusak et al. (2020): When ripe gac powder is added to pasta, it increases the β-carotene content of the product. Adding ingredients containing β-carotene such as carrot residue flour (Porto Dalla Costa et al., 2016) also increased the β-carotene content of pasta. The different percentages of xanthan gum (1 to 2%) did not affect the β-carotene and lycopene content of all macaroni samples.

The firmness. The hardness of pasta can be measured through shear force (Wang et al., 2012). The results showed that the hardness of macaroni decreased from 155.60 ±4.11 to 77.40 ±2.21 g force when the percentage of added Gac aril increased from 3 to 9% (Table 2). The more Gac aril content added, the softer the product structure. The reason is that when increasing the content of gac added to the dough, it also made the dough absorb more water because the moisture content of Gac aril was high (75.97%). In addition, the fiber in Gac aril can break down and weaken the gluten network, thus reducing the hardness of macaroni. However, by increasing the amount of xanthan gum used, the macaroni hardness was significantly improved, which is similar to what was reported by Sandhu et al. (2015). Xanthan gum has the ability to bind molecules in the mixture, create gels and support the formation of the gluten network in macaroni. Gallagher et al. (2004) reported that xanthan gum improved the firmness and toughness of pasta made from bean flour. Furthermore, it has been reported that xanthan gum addition accelerated gel setting. This may be related to better binding between gelatinized starch granules promoted by gum xanthan (Mandala and Bayas, 2004). In addition, xanthan gum retains moisture well during storage, inhibiting the development of cracks on the product surface (Sanguinetti et al., 2015). When the percentage of added xanthan gum increased from 1 to 2%, the hardness of macaroni increased markedly from 77.40 ±2.21 to 155.60 ±4.11 g force.

Table 3. Cooking quality of macaroni with different concentrations of Gac aril and xanthan gum

Xanthan gum %	Gac aril %	Rehydration rate %	Volume increase %	Cooking loss %
1	3	55.82 ±0.94	65.12 ±2.74	3.09 ±0.08
	5	57.89 ±0.83	71.49 ±3.01	3.20 ±0.03
	7	59.63 ±0.63	82.86 ±4.12	3.33 ±0.07
	9	63.23 ±1.10	84.40 ±3.65	3.54 ±0.02
1.5	3	56.41 ±0.65	73.77 ±4.21	2.84 ±0.10
	5	58.27 ±0.93	79.29 ±1.42	2.98 ±0.05
	7	60.12 ±0.82	83.81 ±2.14	3.07 ±0.11
	9	62.80 ±1.12	85.57 ±1.18	3.26 ±0.08
2	3	57.56 ±0.81	76.95 ±2.02	2.61 ±0.07
	5	59.21 ±0.85	81.19 ±1.74	2.75 ±0.06
	7	62.86 ±0.71	85.48 ±2.15	2.92 ±0.08
	9	64.61 ±1.22	92.38 ±3.14	3.03 ±0.04

Notes: Data are expressed as mean ±standard deviation; cooking quality parameters (rehydration rate, volume increase and cooking loss as %) of macaroni samples measured: 55.5–0.50; 65.45–3.20 and 2.85%, respectively.

Effect of Gac aril and xanthan gum addition to cooking quality

The quality of macaroni can be expressed through cooking quality by cooking properties such as rehydration rate (weight increase), volume gain and cooking loss (Özyurt et al., 2015). The subsequent effects of xanthan gum and Gac aril on the cooking quality of pasta were characterized (Table 3).

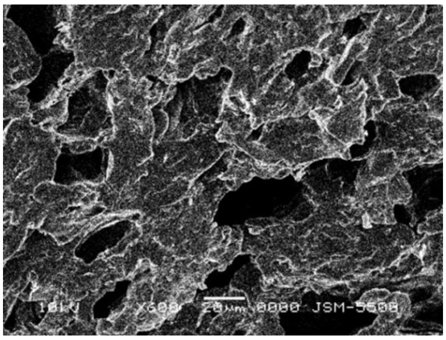
With a fixed amount of added xanthan gum, both rehydration rate (%) and volume of macaroni increased after cooking whilst increasing Gac aril supplement from 3 to 9%. However, there seems to be no difference between 7 and 9% of gac used (based on calculated standard deviation). Similarly, at fixed Gac aril content, the weight and volume of macaroni also increased correspondingly with the added xanthan gum content increasing from 1 to 2%. The obtained values showed a very small difference, compared with the control sample.

The addition of gluten-free ingredients in the production of macaroni reduces the gluten strength of the flour. As a result, the macaroni structure is broken and weakened, which allows more soluble solids to be washed away from the noodles into the cooking water. Fiber in Gac aril also has the ability to retain water, so it increased the rehydration rate of the product. The rehydration rate was noted to increase from 55.82 ±0.94 to 64.61 ±1.02% and volume increase (%) from 65.12 ±2.74 to 92.38 ±3.14% for all Gac arils and gum xanthan concentrations used in the formulations. Water absorption reflects the amount of water bound to the product during cooking, while the swelling index indicates the relative volume change between uncooked and cooked pasta (Oikonomou and Krokida, 2011). Cleary and Brennan (2006) suggested that a volume increase of macaroni may be related to greater water absorption during cooking due to the high water binding capacity of the fiber. Yalcin and Basman (2008a) also reported that noodles prepared with added xanthan gum had higher water absorption and swelling capacity. During cooking, the soluble starch components and soluble fractions, such as non-starch polysaccharides, are transferred to the cooking water. The results showed that the cooking loss increased with the increase of Gac aril supplement. The lowest (2.61 ±0.07%) and the highest (3.54 ±0.02%) values were shown with the percentage of Gac aril supplement of 3% and 9%, respectively. It was observed that if the high content of Gac aril added to the recipe increased the cooking loss, the addition of xanthan gum to the recipe improved the quality of the macaroni and reduced the leaching of its ingredients into the cooking water. When increasing the percentage of xanthan gum supplement used from 1 to 2%, the cooking loss was decreased significantly. This is probably because xanthan gum increased the ability to bind between ingredients in macaroni recipes, forming a good gel network between starch granules and binder, limiting the solubility of starch into water when cooking (Kasunmala et al., 2020). These results are similar to those reported by Yalcin and Basman (2008b) and Ansari et al. (2013): Adding xanthan gum to corn noodles and spaghetti significantly reduced dry matter loss and improved noodle quality. A cooking loss of 6.40–6.50 g/100 g of raw spaghetti was reported (Manthey and Schorno, 2002); Hernández-Nava et al., 2009). However, the lower cooking loss was found (0.93 g/100 g raw spaghetti) by Brennan and Tudorica (2007). A cooking loss of 12% or less is considered to be acceptable and is indicative of good quality pasta (Fu, 2008). Therefore, the macaroni samples from this study can be considered a good quality product as they exhibit cooking losses of 2.61 ±0.07 g/100 g to 3.54 ±0.02 g/100 g for all contents of Gac aril and xanthan gum added to macaroni recipes.

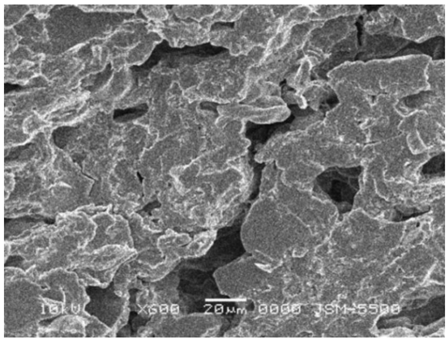
Structural studies of Gac aril-enriched macaroni

A scanning electron microscope (SEM) was used to investigate the structure of the control cooked macaroni sample (without the addition of Gac aril and gum xanthan) and the selected macaroni sample (7% and 1.5% of Gac aril and xanthan gum addition) from a combination all data. Micrographs of control and macaroni – Gac samples show the difference (Fig. 2).

The control sample (Fig. 2a) shows a developed protein network with mostly gelatinized starch. The addition of gac and gum xanthan seems to disrupt the protein-starch substrate, but is denser (Fig. 2b), possibly due to greater protein–fibre interaction (Tudorica et al., 2002). In addition, it can be seen that voids appeared within the structure of pasta supplemented with Gac aril and xanthan gum with



a



b

Fig. 2. SEM micrograph of cooked macaroni with a – control sample (no Gac aril and xanthan gum addition) and b – macaroni with 7% of Gac aril and 1.5% of xanthan gum

a smaller number and size than the control sample, probably because xanthan gum supports co-gelation with flour/starch proteins in the formulation and also egg protein increases firmness of the product. The images in Figure 2 from our study again support this view, with high levels of Gac aril and xanthan gum addition associated with better macaroni structures.

CONCLUSION

The effects of macaroni enrichment with Gac aril and the use of xanthan gum on product quality were noted. The physicochemical components, bioactive compounds, the firmness, microstructure and cooking quality of the analyzed products emphasized the role of the ingredients used in the results obtained. The microstructure of the product is also improved and ensures the desired product quality attributes. The findings also suggested that gac fruit appears to be a promising functional ingredient that can be combined with macaroni to improve quality with enhanced functional ingredients. Further studies are needed in order to apply it at an industrial scale and with high consumer acceptance of this new product.

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