Physicochemical Properties of Semolina-Based Pasta Incorporated with Chickpea Flour and Dried Moringa Leaves

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Abstract: The leaves of *Moringa oleifera,* or moringa, are known to have various health benefits and commonly found in home-cooked dishes such as curries and soups. However, the utilization and application of moringa in food industry is still very limited. Therefore, this study was conducted to determine the physicochemical properties of semolina-based pasta incorporated with chickpea flour and dried moringa leaves purposely to increase the functionality of the produced pasta. The physicochemical properties determined included proximate composition, total dietary fiber, calcium content, texture profile, color, and water activity. The analyses were conducted on three samples: control (CO) pasta, chickpea-containing (CP) pasta, and chickpea and moringa leaves-containing (CM) pasta. In terms of chemical composition, both CP and CM pasta had significantly higher ($p<0.05$) moisture, fat, protein, ash, total dietary fiber, and calcium content than those of CO pasta. In terms of texture, addition of chickpea and moringa leaves generally increased the hardness, springiness, and chewiness index of the pasta. All samples were categorized in the yellow color range and had water activity values of above 0.9. All in all, the addition of chickpea and moringa leaves was found to be able to increase the functional benefit of the pasta produced.

1 INTRODUCTION

Moringa oleifera, or more commonly known as 'moringa', comes from a monogeneric family named *Moringaceae* and usually is found wild and cultivated throughout the plains, especially in hedges and house yards (Qaiser *et al.,* 1973). They also grow well in both countries with humid, hot weather and hot dry lands (Morton, 1991), making them easily found in Southeast Asian countries. Moringa is referred to as 'drumstick tree', 'horse radish tree', 'kelor tree' (Anwar and Bhanger, 2003), and 'Sohanjna' (Qaiser *et al.,* 1973). All parts of moringa, such as the leaves, fruit, flowers, and even the immature pods of the tree, are known to be highly nutritive (Anwar and Bhanger 2003; D'souza and Kulkarni, 1993; Anwar, Ashraf and Bhanger*,* 2005). The leaves, specifically, were reported to contain β-carotene, protein, vitamin C, calcium, potassium, and a good source of natural antioxidants in the form of flavonoids, phenolics, and carotenoids (Dillard and German, 2000; Siddhuraju and Becker, 2003). The fresh leaves, flowers, and tender immature pods are generally consumed in the form of cooked dishes like soups or curries (The Wealth of India, 1985). However, the leaves are sometimes bitter due to the presence of saponins (Makkar and Becker, 1997), and they also disintegrate easily during cooking (Jahn, 1991). Therefore, incorporation of moringa leaves in the form of dried powder into functional foods is suitable as one of the ways in obtaining the nutrients available in the leaves as well as for easier storage and longer shelf life.

Meanwhile, *Cicer arietinum* L., or better known as chickpea, is a part of legume family that is grown and consumed worldwide, especially in the Afro-Asian countries. It is also called as garbanzo bean or Bengal gram (Hirdyani, 2014). Chickpea is generally rich in dietary fiber, low in fat, and a good source of vitamins and minerals such as riboflavin, niacin, thiamine, folate, β-carotene, calcium, and iron (Murty, Pittaway and Ball*,* 2010). Similar to other legumes, chickpea contains significant amounts of all essential amino acid except for the sulfur-containing ones, which can be complemented by adding cereals to the daily diet (Hirdyani, 2014). Due to its nutritional composition, chickpea has been used in various food products to increase their nutritional values with satisfying results both nutritionally and organoleptically, such as biscuits (Yadav, Yadav and Dull*,* 2012), breads (Hefnawy, El-Shourbagy and Ramadan*,* 2012), and wheat crackers (Kohajdova, Karovicova and Magala*,* 2011). There also had been numerous studies about implementation of chickpea

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flour in pasta due to its dietary fiber content, low glycemic index and amino acid content, since durum wheat in pasta is generally rich in sulfur-containing amino acids, which is complementary to the amino acid content of chickpea (Osorio-Diaz *et al.,* 2008; Abou Arab, Helmy and Bareh*,* 2010; Sabanis, Makri and Doxastakis*,* 2006; Bashir, Aeri and Masoodi*,* 2012).

Pasta is one of the most consumed staple food in the world, and it is also considered to be a food that is versatile, inexpensive, easy to store, as well as easy to prepare (Hamblin, 1991). In terms of nutrient content, pasta is low in sodium, low in fat, no cholesterol, low glycemic index, and a rich source of complex carbohydrates (Giese, 1992). As pasta is naturally bland in flavor, it is also easily adaptable when it comes to addition of different types of legumes and vegetables purposely to increase the nutritive value as well as flavor enhancement. Successful studies on incorporation of legumes and beans into pasta other than chickpea included Mexican common bean (*Phaseolus vulgaris* L.) (Gallegos-Infante *et al.,* 2010), split pea (Petitot *et al.,* 2010), faba bean (*Vicia faba*) ((Gimenez *et al.,* 2012), and lentil (Wojtowicz and Moscicki, 2014). Meanwhile, there were also prior studies which involved addition of vegetables into different formulations of pasta, such as amaranth leaves (Borneo and Aguirre, 2008), broccoli (Silva *et al.,* 2013), carrot pomace (Gull, Prasad and Kumar*,* 2015), and yellow pepper (Padalino *et al.,* 2013). However, to date, there had been no study on semolina or durum wheat-based pasta with both chickpea flour and dried moringa leaves added into the formulation. Therefore, the objective of this study is to evaluate the physicochemical properties of semolina-based pasta added with chickpea flour and dried moringa leaves as compared to those of semolina-based and semolina-chickpea-based pasta.

2 MATERIALS AND METHODS

2.1 Materials and Reagents

Semolina flour, dried chickpeas, and moringa leaves were purchased from local supermarket. Chickpea flour was produced by milling (Retsch Ultra Centrifugal Mill ZM 200, Haan, Germany) the dried chickpea, and the resulting flour was stored in vacuum-packed aluminum pouches at room temperature until further usage. Moringa leaves were washed, rinsed, and dried at 50° C for approximately 8 hours until it reached approximately 5% of moisture in the final dried samples. The dried samples were then milled using the centrifugal mill and stored in Schott bottles at room temperature until further usage.

For chemical reagents, anhydrous di-sodium hydrogen phosphate, disodium phosphate monobasic monohydrate, anhydrous sodium carbonate, and hexane were from Friendemann Schmidt Chemical (Washington, USA). Kjeldahl catalyst and Celite 545 were from Sigma-Aldrich (Missouri, USA). 95% ethanol were from John Kollin Corporation (Midlothian, UK). Ammonium sulphate was from USB Corporation (Ohio, USA). Boric acid, acetone, bromocresol green, and methyl red were from Merck KGaA (Darmstadt, Germany). 96% sulphuric acid was from Thermo Fisher Scientific (Massachusetts, US). Hydrochloric acid (HCl) and sodium hydroxide (NaOH) were from R&M Chemicals (Selangor, Malaysia). Total dietary fiber kit was from Megazyme International (Wicklow, Ireland).

2.2 Preparation of Pasta

Three different formulations of pasta were prepared, consisting of control (CO), chickpea-added (CP), and chickpea and moringa-added (CM) pasta. The formulations were as described in Table 1. For the preparation of CO, semolina flour was mixed with distilled water and kneaded until the dough had reached a uniform and adequate consistency for extrusion, in which the pasta dough did not stick on the surfaces of pasta extruder. Similar procedure was conducted for CP pasta by having chickpea flour, and CM pasta by having chickpea flour and dried moringa leaf powder added into the mixture. The amount of chickpea flour and moringa leaf powder added into the formulations was based on preliminary studies. The dough was extruded through Micra pasta extruder (Italgi S.r.l., Italy), and the resulting extruded pasta was covered in thin layer of wheat flour to avoid the pasta strands sticking to each other. The fresh pasta samples were then kept in re-sealable polyethylene bags and stored at refrigerated temperature (±4° C) before further analyses and cooking. Cooking time for all pasta samples was standardized for 3 minutes.

Table 1: Formulations of control pasta (CO), chickpea-added pasta (CP) and chickpea and moringa-added pasta (CM).

Ingredients	CO	CP	CM
Semolina flour (g)	100	100	100
Chickpea flour (g)	-	80	80
Moringa leaf powder (g)	-	-	2
Water (ml)	43	43	43

2.3 Chemical Analyses

Chemical analyses conducted on all samples consisted of determination of moisture, ash, protein, fat, total dietary fiber, and calcium content. All analyses were performed following the official methods of analysis of the Association of Official Analytical Chemists (AOAC, 2012). Carbohydrate content was calculated by difference.

2.4 Texture Profile Analysis

Texture profile of both uncooked and cooked samples was performed using Brookfield CT3 texture analyzer (Middleboro, USA) on hardness, springiness, and chewiness index based on the methodology conducted by Petitot *et al.* (2010) with slight modifications. The texture analyzer was equipped with a 38.1 mm cylindrical probe and the texture profile analysis test was performed at a constant deformation rate of 1 mm/s to 70% of the initial pasta thickness. The test was conducted in two cycles and in triplicates.

2.5 Colorimetry Analysis

Colorimetry analysis was done using ColorFlex EZ Spectrophotometer (HunterLab, Virginia, USA) for L*a*b* values. The spectrophotometer was standardized using a black glass standard and a white tile standard prior to measurement. Samples were put inside a transparent cylinder and placed on top of the sample port. This spectrophotometer gives an average reading and a standard deviation in terms of L* (lightness, 100 = white, 0 = black), a* (+ red; - green), and b* (+ yellow; - blue). Hue angles and chroma values of the samples were calculated following the equations below:

$$Chroma\ (C) = \sqrt{(a^2 + b^2)} \qquad (1)$$

$$Hue\ angle\ (h^o) = tan^{-1}\left(\frac{b}{a}\right) \qquad (2)$$

2.6 Water Activity

Water activity (a_w) was measured using a pre-calibrated water activity meter (AquaLab LITE, Aqualab, Washington, USA). Ground samples were evenly spread on the instrument cups and place onto the water activity meter. Readings of water activity were taken in triplicates.

3 RESULTS AND DISCUSSION

3.1 Chemical Analyses of Pasta

Table 2 shows the results for chemical analyses of all pasta samples. It could be seen that there was a significant increase ($p<0.05$) in moisture content for pasta containing chickpea flour (CP) as well as pasta containing both chickpea flour and moringa leaves (CM) compared to control pasta. This could be due to higher dietary fiber content of CP and CM pasta compared to that of control pasta. Higher dietary fiber content is usually associated with higher water content due to the tendency of dietary fiber to absorb and retain water (Wang, Rosell and de Barber, 2002). This result was in accordance to those obtained by Bashir *et al.* (2012) and Foschia *et al.* (2015) in which addition of chickpea flour and dietary fiber increased the moisture content of pasta.

Both CP and CM pasta also had significantly higher ($p<0.05$) fat, protein, and total dietary fiber content than those of control pasta. This was contributed by the fat, protein, and fiber content of chickpea which was approximately 6%, 25.3-28.9% and 17.4%, respectively (Jukanti *et al.,* 2012). Moringa is also known to be rich in protein, with the value reaching approximately 30.29%. It might also contribute to the fat and fiber content of CM pasta with 6.50g of fat in 100g of leaves and 11.4% of fiber (Moyo *et al.,* 2011).

Lastly, both CP and CM pasta were found to have significantly higher ($p<0.05$) ash and calcium content than those of control pasta. Ash content is commonly positively correlated with total amount of minerals in a sample, which is represented by the results on calcium content. CM pasta is shown to have significantly higher ($p<0.05$) calcium content than that of CP pasta as moringa is a rich source of calcium, with 2009.79mg calcium in 100g of leaves (Oduro, Ellis and Owusu, 2008). Overall, the results were in accordance to those of the study conducted by Dachana *et al.* (2010) in which cookies containing moringa leaves had higher fat, protein, total dietary fiber, and calcium content.

3.2 Texture Profile Analysis of Pasta

Texture profile is considered as the most important physical property of pasta since it is the most recognized quality for consumers (Gull, Prasad and Kumar, 2015). From the results tabulated in Table 3, it can be seen that there was significant difference ($p<0.05$) in terms of hardness of fresh pasta, with CM pasta having the highest hardness value. This result

Table 2: Chemical analyses of control pasta (CO), chickpea-added pasta (CP) and chickpea and moringa-added pasta (CM).

Pasta Samples	Moisture (%)	Fat (%)	Protein (%)	Total dietary fiber (%)	Ash (%)	Calcium (mg/100g)	Carbohydrate (%)
CO	25.210±0.050^{a}	0.190±0.010^{a}	11.490±0.040^{a}	4.950±0.230^{a}	0.008±0.000^{a}	31.000±0.590^{a}	63.100
CP	27.390±0.480^{b}	0.750±0.130^{b}	13.690±0.010^{b}	5.160±0.550^{a}	0.019±0.000^{b}	58.000±0.590^{b}	58.150
CM	27.360±0.450^{c}	0.880±0.030^{c}	14.250±0.010^{c}	13.790±0.210^{b}	0.017±0.005^{c}	108.000±0.580^{c}	57.490

was in accordance to a prior study conducted by Petitot *et al.* (2010) in which fortifying pasta with 35% legume flour significantly increased the hardness of pasta due to the increase in protein content and fiber. Among all pasta samples, CM pasta also happened to be the one with the highest protein content and fiber (Table 2). However, the trend changes once the pasta was cooked, in which CP pasta was the one with the highest hardness value. This might be due to the boiling process which caused the fiber in CM pasta to absorb more water than that of CP pasta as fiber is known to have high affinity of water (Wang, Rosell and de Barber*,* 2002). Legumes were also correlated with lower water uptake compared to durum wheat in pasta and insoluble fibers in moringa leaves (Petitot *et al.,* 2010).

Table 3: Texture profile analysis of control pasta (CO), chickpea-added pasta (CP), and chickpea and moringa-added pasta (CM).

Parameters	Pasta Samples	Texture Profile Analysis	
		Uncooked	Cooked
Hardness (g)	CO	631.670±114.370^{a}	649.670±110.530^{a}
	CP	727.000±224.177^{b}	2954.330±296.290^{b}
	CM	1405.670±230.220^{c}	1590.330±198.080^{c}
Springiness (cm)	CO	0.103±0.070^{a}	0.630±0.060^{a}
	CP	0.230±0.040^{a}	0.170±0.040^{b}
	CM	0.137±0.060^{a}	0.210±0.010^{c}
Chewiness index (g)	CO	14.000±6.930^{a}	369.000±51.110^{a}
	CP	40.670±8.020^{b}	68.670±277.590^{a}
	CM	62.330±37.420^{c}	341.670±177.020^{a}

For springiness, it was found that there was insignificant difference ($p>0.05$) among all uncooked pasta samples, but there was significant difference ($p<0.05$) in values once the pasta samples were cooked, with control pasta having the highest springiness value. This could be attributed by the gluten protein content in control pasta which was not substituted with chickpea flour and moringa leaves. Gluten is the type of protein responsible for the elasticity of products which contain wheat flour, including pasta, and it mainly affects the water absorption, swelling index, optimum cooking time, cooking loss, texture, appearance, and taste of pasta in general. Inclusion of dietary fiber in the form of chickpea flour and moringa leaves would affect the integrity of protein-starch network, resulting in lower values of springiness especially after cooking (Foschia *et al.,* 2015). This also might be the reason why, albeit insignificant, control pasta had the highest chewiness index value after cooking.

3.3 Colorimetry Analysis of Pasta

In terms of colorimetry analysis, it was found that there were significant differences ($p<0.05$) for all parameters involved. Uncooked control pasta had the highest lightness (L*) value, followed by CP pasta and CM pasta. This was attributed by the supplementation of chickpea flour and moringa leaves which have darker color than semolina. However, CP pasta had the highest lightness value after cooking, followed by control pasta and CM pasta. The results were in accordance to the study performed by Islas-Rubio *et al.* (2014) in which there was generally a decrease in lightness values after cooking of both semolina pasta and pasta containing amaranth. Meanwhile, both uncooked and cooked pasta samples had their a* and b* values within the positive range of red and yellow hue due to the presence of color pigments such as carotenoids and xanthophyll. Besides L* value, b* value is considered as the other important color parameter for pasta as it describes the yellowness (Rayas-Duarte, Mock and Satterlee, 1996). Decrease in yellowness after cooking was found in all samples, which might be due to degradation and/or leaching of color pigments, such as carotenoids and xanthophyll, in pasta during cooking (Wood, 2009).

In terms of chroma values of uncooked pasta samples, CM pasta was found to have the highest intensity, followed by CP pasta and control pasta. The intensity of CM pasta reduced significantly after cooking, resulting in CP pasta to have the highest chroma value, followed by CM pasta and control pasta. The decrease in the chroma value of CM pasta might be due to the leaching of color pigments during cooking process, which was also shown by the increasing lightness value of CM pasta after cooking. Lastly, for hue angle, the color of all pasta samples was still within the category of yellow hues, with the color of CM pasta moving towards the category of green hues due to the presence of chlorophyll A as the most contained color pigment in moringa leaves (Mbailao, Mianpereum and Albert, 2014).

Besides texture of pasta, color of pasta is also an important quality factor for consumers as it influences choice and preferences. Based on the results obtained, CM pasta was shown to have darker color shade compared to semolina-based control pasta and chickpea-containing CP pasta. However, some consumers may accept dark-colored pasta as they are usually associated with better nutritional value (Islas-Rubio *et al.,* 2014).

Table 4: Colorimetry analysis of control pasta (CO), chickpea-added pasta (CP), and chickpea and moringa-added pasta (CM).

Parameters	Pasta Samples	Colorimetry Analysis	
		Uncooked	Cooked
L*	CO	75.090±0.030^{a}	63.250±0.010^{a}
	CP	70.640±0.040^{b}	68.800±0.010^{b}
	CM	52.410±0.030^{c}	53.630±0.004^{c}
a*	CO	1.820±0.010^{a}	1.130±0.010^{a}
	CP	4.070±0.010^{b}	2.260±0.010^{b}
	CM	0.600±0.010^{c}	0.660±0.010^{c}
b*	CO	17.920±0.030^{a}	17.200±0.030^{a}
	CP	26.650±0.010^{b}	19.000±0.010^{b}
	CM	31.260±0.030^{c}	18.200±0.010^{c}
Chroma (C)	CO	18.010	17.240
	CP	26.960	19.130
	CM	31.270	18.210
Hue angle (h°)	CO	84.200	86.240
	CP	81.320	83.220
	CM	88.900	87.920

3.4 Water Activity of Pasta

Based on the results tabulated in Table 5, there was significant difference ($p<0.05$) in the water activity of all uncooked samples, but insignificant difference ($p>0.05$) was found for those of cooked pasta samples. Uncooked control pasta had the highest water activity, followed by CP pasta and CM pasta. Since CP and CM pasta had higher moisture content than control pasta, this indicates that some constituents in CP and CM pasta caused the water to be unavailable, most likely to be protein and fiber (Tudorica, Kuri and Brennan, 2002). Meanwhile, increase in water activity of cooked pasta samples was because of gelatinization process happening during cooking, which led to further penetration of water into food matrix and formation of multilayer water adsorption (Grzybowski and Donnelly, 1977).

Table 5: Water activity of control pasta (CO), chickpea-added pasta (CP), and chickpea and moringa-added pasta (CM).

Pasta Samples	Water Activity (measured at 25±1°C)	
	Uncooked	Cooked
CO	0.938±0.005^{a}	0.962±0.007^{a}
CP	0.926±0.003^{b}	0.957±0.002^{a}
CM	0.900±0.005^{c}	0.968±0.002^{a}

4 CONCLUSIONS

Semolina-based pasta incorporated with chickpea flour and dried moringa leaves was successfully developed. Albeit having significantly different values for texture attributes, out of the three samples, pasta sample containing both chickpea flour and dried moringa leaves was found to have more functional benefits as it has the highest protein, total dietary fiber and calcium content. The pasta was also found to have darker colour than those of control and chickpea flour-containing pasta, but consumers tend to accept dark coloured pasta as they are usually associated with better nutritional values. This shows that semolina-based pasta containing chickpea flour and dried moringa leaves has the potential to be one alternative of functional pasta product.

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