International Food Research Journal 26(4): 1249-1257 (August 2019)

Journal homepage: *http://www.ifrj.upm.edu.my*

The effect of oyster mushroom (*Pleurotus sajor-caju*) flour incorporation on the physicochemical quality and sensorial acceptability of pasta

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Article history

Received: 29 March, 2018
Received in revised form: 23 December, 2018
Accepted: 23 April, 2019

Keywords

Oyster mushroom flour
Pasta
Physicochemical properties
Sensorial acceptability

Abstract

The present work was carried out to formulate a pasta with oyster mushroom flour (OMF), and to evaluate the effect of its addition on the nutritional compositions, physicochemical properties, and sensorial acceptability of the formulated pasta. Four pasta formulations with different levels of OMF (0%, 5%, 10%, and 15%) were developed prior to the determination of the nutritional composition, physicochemical properties, and sensorial acceptability. Proximate components such as protein, ash, and fat increased with increasing OMF levels except for carbohydrates and energy, which were decreased with increasing OMF levels. Lightness (L^*) and yellowness (b^*) significantly decreased with increasing OMF levels, while redness (a^*) increased with increasing OMF levels. The results showed that the optimum cooking time, elasticity, firmness, and shear work decreased with increasing OMF levels, while there were no significant differences in hardness or adhesiveness between the samples. In sensory evaluation, the pasta fortified with up to 10% OMF was generally well accepted by the sensory panellists. The addition of 10% OMF into the pasta resulted in an increase in its nutritional values, thus affecting its physicochemical properties, and improving some of its sensorial attributes..

Introduction

Chronic non-communicable diseases are a leading cause of disability and death, and they increasingly affect people in both developed and developing countries. Chronic non-communicable diseases account for almost 60% of global mortality, and 80% of these deaths are reported from low- and middle-income countries (Unwin *et al*., 2006). Disease studies in Malaysia have ranked hypertension, obesity, smoking, diabetes, high cholesterol, and high body mass index (BMI) as the second biggest contributors to both disability adjusted life-years (DALY) and deaths (IPHM, 2015).

Among many kinds of edible mushrooms, oyster mushrooms (*Pleurotus* spp.) have notably been commercialised and consumed. They not only exhibit excellent taste but also contain high levels of nutritious components, including proteins, carbohydrates, vitamins and minerals. In addition, many research findings have revealed that oyster mushrooms can prevent and reduce several serious diseases, including high blood pressure and cholesterol (Agrawal *et al*., 2010), breast cancer, and prostate cancer (Jedinak and Sliva, 2008). One of the functional compounds that commonly occurs in mushrooms, β-glucan, is associated with lowering blood cholesterol levels and the glycaemic response *in vivo*; however, scant information is available about the levels that exist in edible mushrooms (Bobek *et al*., 2001). The dried oyster mushroom is high in total dietary fibre (33.00-56.99%) and β-glucan (3.32-25.83%) content (Aishah, 2013; Ng *et al*., 2017). Furthermore, the incorporation of oyster mushroom flour (OMF) into food products to partially replace wheat flour is purported to increase the dietary fibre content of said foods. As new ingredients emerge, it is important to understand their functionality and their effects on formulations. This manner of increasing fibre levels could be useful for ensuring that the population receives adequate amounts of fibre (Baixauli *et al*., 2008).

Around the world, pasta products are preferred for their ease of cooking, low price, long shelf-life and versatility (Bergman *et al*., 1994). Due to its high carbohydrate content, pasta is used primarily as

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energy source. To enhance their nutritional properties, pasta products have been fortified with different types of nutritious ingredients from various sources. Ordinary durum wheat pasta contains, on average, 77% carbohydrates and can have even less than 10% protein (Filip and Vidtih 2015). Supplementation with oyster mushroom powder to partially replace the wheat flour in pasta is intended to improve this nutritional composition since oyster mushroom powder contains a significant amount of protein (22.4%) and dietary fibres (57.0%), as reported by Ng *et al*. (2016). Numerous studies have explored the addition of ingredients, for example, germinated pigeon pea (*Cajanus cajan*) seeds, wakame seaweed (*Undaria pinnatifida*), and amaranth (*Amaranthus* spp.) leaf meal, with the purpose of increasing the nutritional value of pasta made from wheat flour (Torres *et al*., 2007b; Borneo and Aguirre, 2008; Prabhasankar *et al*., 2009). If nutritious ingredients could be substituted into pasta preparation, pasta could be suitably considered as a functional food.

It is possible to use non-durum semolina wheat ingredients to create specifically blended pasta even though pasta is usually manufactured using durum semolina wheat flour (Brennan *et al*., 2004). Therefore, the aim of the present work was to evaluate the effect of substituting wheat flour with different levels of oyster mushroom flour (OMF) as a functional ingredient in the nutritional composition, physicochemical properties, and sensorial acceptability of pasta.

Materials and methods

Sample

Oyster mushrooms (*Pleurotus sajor-caju*) grown on a sawdust substrate were used in the present work. Clusters of mushrooms, grown within 6-8 d after spawning, were harvested by using clean scissors so that no extra mushroom mycelium would be teased. Next, 5 kg harvested mushrooms were dried using the low-heat air-dried technique (50-55°C), established by Anjaad Industries (M) Sdn. Bhd. The dehydrated OMF (yield 10% w/w) was milled into powder using an electric blender (Waring Commercial 8010S, USA), and sifted into fine powder using a sieve with a mesh diameter of 125 µm. The collected OMF was then kept in screw cap bottles and stored at 4°C until further use.

Development of pasta

The pasta was produced in a fettuccine shape, adapted from the formulation developed by the Malaysia Agricultural Research and Development Institute (MARDI, 1994) with a slight modification on the ingredients' composition used. The original ingredient of wheat flour was added with OMF at 5%, 10% and 15%. These OMF-based pastas were compared with a control pasta, which was made of 100% wheat flour (0% OMF).

Firstly, the all-purpose wheat flour was thoroughly mixed with OMF in a mixing bowl. Then, salt, sodium bicarbonate and permitted egg yellow colour essence were added into the filtered water and mixed until completely dissolved. Next, the mixture was added into the flour, and the composite was manually kneaded until it was completely homogenous and consistent. After that, the dough was extruded using a pasta machine (MARCATO, WN16195-150, China). The dough was then cut crossways in pieces that were approximately 25 cm long. Finally, the pasta was dried at 60°C for 2.5 h in a hot air-oven (Memmert GmbH and Co. KG, Germany), which was followed by cooling to 25°C. While waiting for further analyses, the pasta was stored at room temperature and labelled in four different air-tight plastic containers according to their formulations.

Analyses of the nutritional compositions

Pasta samples were analysed for moisture (standard air-oven method 925.10), total ash (method 942.05), fat (method 960.39), protein (Kjeldahl method 991.20), and total dietary fibre (enzymatic-gravimetric method 991.43), according to the standard analytical method (AOAC, 2000a). The samples' β-glucan levels were determined using a Mixed-Linkage Beta-glucan Test Kit (Megazyme International Ireland Ltd., Ireland). The procedures included the Mixed-Linkage Beta-Glucan (Streamlined Method) AOAC (2000b) Method 995.16, the AACC Method 32-23 (AACC, 2000), and the ICC Standard Method No. 168. The carbohydrate contents of the products were determined by calculating the percent remaining after all the other components were measured, as follows:

$$\text{Total carbohydrate} = 100 - (\%\ \text{moisture} + \%\ \text{ash} + \%\ \text{fat} + \%\ \text{protein})$$

The energy (kcal/100 g) value of the product was determined by the following formula: Carbohydrate: 1 g = 4 cal; Protein: 1 g = 4 cal; and Fat: 1 g = 9 cal.

Optimum cooking time

Briefly, 25 g pasta was broken into lengths of 5 cm, which were then cooked in boiling water. The optimum cooking time (OCT) was evaluated every 30 s during the cooking by observing the time of the disappearance of the starchy white core of the pasta and by squeezing it between two transparent glass slides, according to the AACC-approved method 66-50 (AACC, 2000). The time at which the core completely disappeared was taken as the OCT.

Colour properties

The colour of the sample was measured using a Minolta spectrophotometer (CM-3500d Co. Ltd, Osaka, Japan). The instrument was calibrated using a Zero Calibration Box and a White Calibration Plate before analysis, and the average values of the three replicates were reported. The surface colour was measured using the L^*, a^*, b^* scales as lightness (white to black), redness (red to green), and yellowness (yellow to blue) indications, respectively.

Texture profile analyses

The cooked pasta texture was assessed using a TA.XTPlus texture analyser (Stable Micro Systems Ltd., Surrey, UK) for elasticity (or 'tensile strength'), hardness, adhesiveness, firmness and shear work. Details of the instrument settings are described in the manual for the texture analyser. For each test, the pasta strands were cooked at the OCT, drained, rinsed, and left for 15 min prior to testing. Following the tests, the values for the analyses were automatically obtained by MACRO, which was driven by the Exponent software package.

Elasticity

Spaghetti tensile grips (A/SPR) were used as the accessory in this test. The setting was performed under the following states: a test mode of measuring force under tension; a test option of returning to start; a pre-test speed of 1.0 mm/s; a test speed of 3.0 mm/s; a post-test speed of 10.0 mm/s; a distance of 100 mm; a load cell of 5 kg; and a trigger type of auto-5 g.

Firmness and shear work

The accessory used in this test was an AACC 1 mm, flat, Perspex blade knife (A/LKB-F). The setting was performed under the following states: a test mode of measuring force in compression; a test option of returning to start; a test speed of 0.17 mm/s; a post-test speed of 10.0 mm/s; a distance of 4.5 mm; a load cell of 5 kg; and a trigger type of 'button' (from a starting height of 5 mm).

Hardness and adhesiveness

The accessory used in this test was a 35 mm cylinder probe (P/35). The setting was performed under the following states: a test mode of measuring force in compression; a test option of returning to start; a pre-test speed of 2.0 mm/s; a test speed of 2.0 mm/s; a post-test speed of 2.0 mm/s; a strain of 45%; a load cell of 5 kg; and a trigger type of auto-10 g.

Sensory evaluation

Cooked pasta samples were served to a panel of 60 untrained volunteers. They were randomly selected among staff and students from the School of Health Sciences, Universiti Sains Malaysia. Four samples from the different pasta formulations were served to each panellist individually. They were given a short briefing before the testing session. They were also provided with drinking water to rinse their palate before testing the next sample in order to minimise bias from previous sample. The panellists were asked to indicate the appearance, aroma, colour, flavour, texture, aftertaste and overall acceptability for all samples. A seven-point hedonic rating scale, where 1 corresponded to "dislike the most", 7 to "like the most", and 4 to "moderately like", was used to quantify each attribute (Aminah *et al*., 2000).

Statistical analysis

Statistical analyses were performed using the GraphPad Prism Software (Version 6.01, USA). The results were expressed as the mean ± SEM. The results were analysed for significance using one-way analysis of variance (ANOVA). Tukey's post-hoc test was done for pairing comparison. All tests were 2-tailed, and the significant values were set at p = 0.05.

Results and discussion

Nutritional composition

The results from the nutritional composition analyses of the pastas are summarised in Table 1. Generally, all components were found to increase proportionally with the level of OMF added into the pasta formulations except for carbohydrates and energy, which decreased with increasing OMF levels.

Ash content

The mean values of the total ash significantly increased with increasing OMF levels in the pasta formulation. The control pasta contained 0.92% total ash, while the pasta formulations with 5%, 10%, and 15% OMF were recorded as having 1.17, 1.54, and 1.70% total ash, respectively. In accordance with the findings of other studies, the increments of total ash were also observed in creaming cakes (Aishah, 2013) and biscuits (Ng *et al*., 2017) fortified with OMF as well as in pasta ingredients replaced with wakame powder (Prabhasankar *et al*., 2009), cowpea

Table 1. Nutritional composition of pasta (g/100 g) formulated with different levels of OMF.

Component (%)	Levels of OMF incorporation (%)			
	0	5	10	15
Moisture	9.06 ± 0.84	9.17 ± 0.02	9.25 ± 0.05	9.37 ± 0.01
Total ash	0.92 ± 0.03	1.17 ± 0.02[c]	1.54 ± 0.01[d,g]	1.70 ± 0.04[d,g,h]
Crude fat	0.03 ± 0.01	0.11 ± 0.03[a]	0.28 ± 0.01[d,f]	0.40 ± 0.01[d,g,i]
Protein	9.95 ± 0.47	10.89 ± 0.08	12.07 ± 0.21[b]	12.20 ± 0.06[b,e]
Carbohydrate	80.04 ± 1.18	78.65 ± 0.07	76.87 ± 0.23[a]	76.33 ± 0.09[a]
Total dietary fibre	3.75 ± 1.19	6.13 ± 0.40	7.81 ± 0.17	11.30 ± 1.56[a]
Beta-glucan	0.44 ± 0.03	0.73 ± 0.03	0.76 ± 0.11	1.13 ± 0.13[b,e]
Energy (kcal/100 g)	360.08 ± 4.75	359.15 ± 0.36	358.28 ± 0.38	357.72 ± 1.98

a = $p < 0.05$; b = $p < 0.01$; c = $p < 0.001$; d = $p < 0.0001$ compared to 0% OMF pasta; e = $p < 0.05$; f = $p < 0.001$; g = $p < 0.0001$ compared to 5% OMF pasta; h = $p < 0.05$; i = $p < 0.01$; compared to 10% OMF pasta.

flour (Herken *et al*., 2007), oregano and carrot leaf (Boroski *et al*., 2011), and germinated pigeon pea flour (Torres *et al*., 2007b).

Ash refers to the inorganic residue that is left following the removal of the water and organic matter by heat in the presence of oxidising agents (McClements, 2003). From a nutrition science standpoint, OMF could improve the mineral contents of pasta; this is supported by the findings obtained in the present work, which indicated that the ash contents in the pasta increased with increasing OMF levels.

Moisture content

The moisture contents of both the wheat flour and OMF, which were pre-determined before mixing, were 11.00% and 8.84%, respectively. The moisture contents in the pasta with OMF incorporated ranged from 9.17 to 9.37% while the pasta without OMF contained less moisture (9.06%). Thus, the addition of the OMF slightly increased the moisture, but no statistical difference was found in the pasta with different levels of OMF added. The oyster mushrooms naturally possess high water content and water holding capacity; and this might have caused the higher moisture content detected in the pasta with added OMF. Furthermore, the sugars, starch, and dietary fibre that exist in OMF might also have contributed, as they can contain a large amount of water (Mohamed *et al*., 2010).

Concurrently, increased moisture content values have also been documented by Aishah (2013) in creaming cakes with added OMF. On the contrary, other findings documented that OMF-enriched biscuits contained lower moisture contents, as compared to control biscuits (Ng *et al*., 2017). However, this might be due to the fact that biscuits were oven-baked (180°C) as compared to pasta (60°C) and creaming cakes (160°C). Furthermore, biscuits are considered very low-moisture-content products, as the thermal processing brings down the final moisture content (ranging from 1 to 5%) in the food product.

Fat content

Fat contents ranged from 0.11 to 0.40% in the pasta with OMF incorporated while pasta without OMF contained less crude fat (0.03%). The increments of crude fat content were also reported in OMF-enriched biscuits (Ng *et al*., 2017), and in a few studies concerning pasta ingredients incorporating composite flours (Herken *et al*., 2007; Torres *et al*., 2007b; Prabhasankar *et al*., 2009; Boroski *et al*., 2011). However, lower crude fat contents were documented when OMF was added into creaming cakes (Aishah, 2013). This might be due to the fact that the OMF used in the creaming cakes' formulation had a low-fat content (1.7%).

Protein content

The control and the 5% OMF pasta contained 9.95 and 10.89% protein, respectively, which did not differ significantly. However, both pastas containing 10% and 15% OMF had significantly higher protein contents (12.07% and 12.20%, respectively), as compared to the control pasta. There was no significant difference between the 5% and 10% OMF pastas. Nonetheless, the 5% OMF pasta had significantly lower protein content than the 15% OMF pasta. In addition, the 15% OMF pasta also showed no significant difference from the 10% OMF pasta.

Essentially, the protein content increased as the OMF levels increased. This showed that the nutrient content of the pasta substituted with OMF was better than pasta without OMF (the control pasta). This might be due to the fact that the OMF used in the present work had a high amount of protein, ranging between 21.01 to 22.41%. Similar findings related to the increased values of protein in pasta were also observed in previous studies (Herken *et al*., 2007; Torres *et al*., 2007a; Prabhasankar *et al*., 2009; Gallegos-Infante *et al*., 2010; Boroski *et al*., 2011).

Carbohydrate content

The carbohydrate contents in the pastas were found to decrease with increasing OMF levels. The mean carbohydrate content of the control pasta (80.04%) did not differ significantly with the addition of 5% OMF, which resulted in 78.65% carbohydrates. However, at 10% and 15% levels of OMF, the carbohydrate content was significantly lower as compared to the control formulation. However, the 10% and 15% OMF pasta did not differ significantly from each other. The pastas with 10% and 15% OMF contained 76.87 and 76.33% carbohydrates, respectively.

A similar finding was presented by Ng *et al*. (2017), who fortified biscuits with OMF. A study conducted by Herken *et al*. (2007) also reported a similar pattern of decreased carbohydrate contents when macaroni samples were enriched with cowpea flour. In another study, Aishah (2013) documented that carbohydrate contents increased when OMF was incorporated in creaming cakes although this might be due to the creaming cakes' different formulations.

Total dietary fibre content

The total dietary fibre (TDF) contents in the pasta with OMF incorporated ranged from 6.13% to 11.30% while the pasta without OMF contained less TDF (3.75%). Only the 15% OMF pasta (11.30% TDF) was found to be significantly higher than the control pasta in TDF. This finding could be attributed to the natural dietary fibre content contributed by the OMF. Hence, this result denotes that OMF could be considered as an alternative food ingredient to increase the dietary fibre content of pasta and other carbohydrate-based products.

Earlier studies performed by Aishah (2013) and Ng *et al*. (2017) also found that the addition of OMF increased the TDF content. In addition, Prabhasankar *et al*. (2009) and Torres *et al*. (2007a; b) also observed that TDF contents were increased when composite flours were replaced in their products. Dietary fibre helps maintain peristalsis (promoting bowel movement), and the slowing or stopping of peristalsis leads to constipation. Constipation, in addition to the discomfort it can bring, has been associated with a range of diseases and disorders, including varicose veins. Dietary fibre is also an excellent binder of toxins as well as certain nutrients in foods. Even though the binding of toxins can protect the body, excess fibre consumption may limit the absorption of essential vitamins and minerals (Shewfelt, 2009).

Beta-glucan content

Among all formulations, the β-glucan content was the highest in the pasta with 15% OMF added (1.13%). The control pasta had 0.44% β-glucan while the 5% and 10% OMF pasta had 0.73% and 0.76% β-glucan, respectively. The results showed that the 15% OMF pasta had significantly higher β-glucan than both the control and the 5% OMF pasta. Previously, linearly increasing levels of β-glucan contents have also been shown with increasing levels of OMF substituted in creaming cakes and biscuits (Ng *et al*., 2017). Mushrooms have been considered as a functional food due to their medicinal properties that are attributable to the presence of β-glucan. They have exhibited significant beneficial health effects, such as hypocholesterolaemia, an anti-tumour nature, and immunomodulatory activities (Kim *et al*., 2011; Samsudin and Abdullah, 2019).

Calorific value (kcal/100 g)

The calorific values of the pastas were found to decrease with increasing OMF levels even though these were not significant. Increasing the levels of OMF in the pasta formulations resulted in decreasing the calorific value by 0.3-0.7%. On the other hand, Torres *et al*. (2007b) reported that spaghetti supplemented with germinated pigeon pea flour showed an increase in the energy value (358.19 kcal/100 g) when compared with control spaghetti (320 kcal/100 g). However, this could possibly be due to the different types of ingredients used in that study as compared to in the present work, which contained differing and diverse amounts of calories.

Optimum cooking time

The optimum cooking time (OCT) of the OMF pastas are shown in Figure 1. The results showed that OCT decreased with increasing OMF levels. The control pasta was cooked optimally at 7.17 min while the pasta with 5%, 10%, and 15% OMF yielded OCTs of 4.67, 4.00, and 3.67 min, respectively. The mean values of the OCTs of all OMF-based pasta were significantly lower than the control pasta. However, there was no significant difference in the OCT between the various levels of OMF pasta. This outcome might be due to the fact that the addition of OMF reduced the quantity of gelatinised starch, which then constituted a loss of stability in the protein-starch linkage. In fact, the lack of stability in the protein-starch linkage appeared to assist the water dispersion over the pasta matrix, decreasing the time that the water needed to reach the core of the pasta during cooking (Padalino *et al*., 2013).

In previous studies, many researchers discovered that the OCT of pasta was decreased when using composite flour as an ingredient. Torres *et al*. (2007b) found that increases in the concentration of germinated pigeon pea seed flour in pasta products led to shorter cooking times. In another study, the fortification of pasta with legume flour also reduced the OCT of dried pasta (Petitot *et al*., 2010a). Additionally, a study by Padalino *et al*. (2013) further observed that the cooking time for spaghetti with a base of yellow pepper flour was shorter than that of a control spaghetti sample. In comparison, Aravind *et al*. (2013) reported that the cooking time was only slightly reduced in resistant-starch-incorporated pasta as compared to the control.

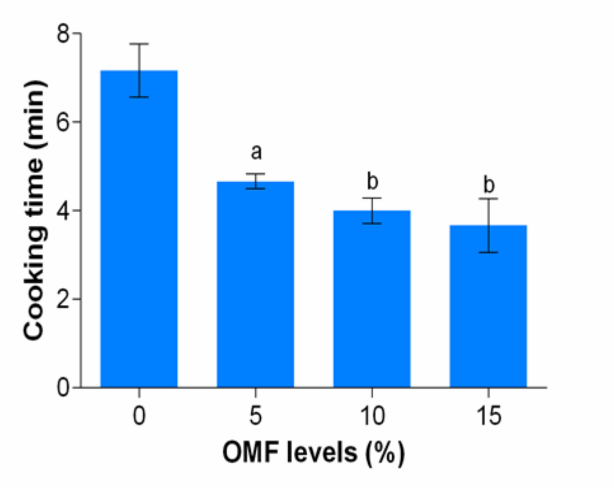

Figure 1: Optimum cooking time of pasta formulated with different levels of OMF . a = $p < 0.05$; b = $p < 0.01$ compared to 0% OMF pasta.

Colour properties

Table 2 shows the effects of OMF addition on the colour of the pastas. In general, lightness ($L*$) and yellowness ($b*$) attributes were significantly lower with increasing OMF levels, but redness ($a*$) was significantly higher with increasing OMF levels. The incorporation of OMF into the pasta formulations resulted in lower $L*$ values as compared to the control pasta; the lightness of the pasta with OMF added at several levels (5%, 10%, and 15%) was recorded between 44.28 to 52.60 $L*$ values while the control pasta had a 56.08 lightness intensity. This agrees with previous studies on pasta with added split pea and fava bean flours (Petitot *et al*., 2010b) as well as chickpea flours (Wood, 2009).

The substitution of OMF into the pasta formulations resulted in higher $a*$ values as compared to the control pasta. Redness in the pasta with 0%, 5%, 10%, and 15% OMF levels was demonstrated at 3.86, 5.83, 5.98, and 6.97 $a*$ values, respectively. Concurrently, increased $a*$ values have also been observed in durum wheat spaghetti formulated with soluble fibre (Aravind *et al*., 2012), macaroni supplemented with cowpea flour (Herken *et al*., 2007), and pasta with fava bean flour incorporated (Petitot *et al*., 2010b).

Moreover, pasta with added OMF was less yellow as compared to the control pasta. The yellowness intensity of the pasta with OMF incorporated at various levels (5%, 10%, and 15%) was recorded between 27.10 to 28.29 $b*$ values while the control pasta had a $b*$ value of 33.61. A significant decrease in pasta yellowness was also reported by Aravind *et al*. (2012; 2013). On the other hand, a study by Ng *et al*. (2017) regarding OMF-enriched biscuits documented opposing findings. This may be due to the different ingredients and the dissimilarity between the cooking processes conducted in Ng *et al*. (2017) study as compared to the present work.

Table 2. Colour of pasta formulated with different levels of OMF.

Colour parameter	Levels of OMF incorporation (%)			
	0	5	10	15
$L*$	56.08 ± 0.01	52.60 ± 0.01^{a}	51.83 ± $0.01^{a,b}$	44.28 ± $0.00^{a,b,c}$
$a*$	3.86 ± 0.01	5.83 ± 0.01^{a}	5.98 ± $0.00^{a,b}$	6.97 ± $0.01^{a,b,c}$
$b*$	33.61 ± 0.02	28.29 ± 0.02^{a}	27.71 ± $0.01^{a,b}$	27.10 ± $0.01^{a,b,c}$

a = $p < 0.0001$ compared to 0% OMF pasta; b = $p < 0.0001$ compared to 5% OMF pasta; c = $p < 0.0001$ compared to 10% OMF pasta.

Texture profiles

The results of the effect of OMF on the texture profiles of the pastas are summarised in Table 3. The elasticity, firmness and shear work significantly decreased with increasing OMF levels. Meanwhile, there were no significant differences between any of the samples on the pastas' hardness or adhesiveness.

Elasticity

The control pasta had an elasticity of 83.19 g while the pasta with 5%, 10%, and 15% OMF had 43.87, 30.92, and 19.94 g of elasticity, respectively. Thus, the substitution of OMF increased the pasta's elasticity by 50-76% (the smaller the number, the more elastic the pasta). This result agrees with a study by Petitot *et al*. (2010b), who found that the addition of split pea and fava bean flour improved pasta elasticity in the range of 30-40%.

Table 3. Texture profiles of pasta formulated with different levels of OMF.

Texture parameter	Levels of OMF incorporation (%)			
	0	5	10	15
Elasticity (g)	83.19 ± 1.15	43.87 ± 1.60[b]	30.92 ± 1.09[b,c]	19.94 ± 0.67[b,d,f]
Firmness (g)	182.5 ± 3.11	128.2 ± 2.58[b]	88.09 ± 3.21[b,d]	60.48 ± 2.18[b,d,f]
Work of shear (gs)	813.80 ± 35.03	590.20 ± 15.07[a]	352.10 ± 20.55[b,c]	236.60 ± 24.70[b,d,e]
Hardness (g)	5·993.00 ± 334.10	5·774.00 ± 219.20	5·602.00 ± 275.70	5·323.00 ± 92.12
Adhesiveness (gs)	258.80 ± 26.30	227.10 ± 3.07	225.00 ± 53.33	181.50 ± 9.68

a = $p < 0.01$; b = $p < 0.0001$ compared to 0% OMF pasta; c = $p < 0.001$; d = $p < 0.0001$ compared to 5% OMF pasta; e = $p < 0.05$; f = $p < 0.001$ compared to 10% OMF pasta.

Firmness and work of shear

In pasta with OMF incorporated, the firmness ranged from 60.48 to 128.2 g while the control pasta was firmer (182.5 g; the smaller the number, the less firm the pasta). Additionally, pasta with OMF added demonstrated less shear work as compared to the control pasta. The shear work values of the pasta with OMF incorporated at various levels (5%, 10%, and 15%) were recorded between 236.60 to 590.20 g sec while the control pasta demonstrated 813.8 g sec. Decreased values of firmness were also reported by Zandonadi *et al*. (2012) concerning green banana pasta, and by Aravind *et al*. (2012) regarding spaghetti enriched with soluble fibre.

Hardness and adhesiveness

Both hardness and adhesiveness attributes showed a decreasing pattern in the results, but there were no significant differences between the levels of the OMF substitutions. Upon increasing the levels of the OMF, hardness decreased by 4-11% while adhesiveness decreased by 12-30%. Padalino *et al*. (2013) also observed that the hardness parameter was statistically lower in spaghetti formulated with vegetable flour as compared to the control spaghetti.

In comparison, the opposite outcome was reported by Petitot *et al*. (2010b) who described that the substitution of durum wheat with split pea and fava bean flour increased the pasta hardness significantly. However, this may be due to the fact that the previous study used different ingredients as compared to the present work. Other than that, the researchers also added higher concentrations of split pea and fava bean flour (35%) in their sample, which could lead to incremental increases of pasta hardness, as compared to the present work (5-15% OMF). Generally, the introduction of OMF resulted in more elastic, less firm, less hard and less sticky pasta.

Sensory acceptability

Table 4 summarises the values for all attributes of the pastas with added OMF, as judged by the untrained panellists. Pasta fortified with up to a 10% OMF substitution was generally well accepted (a rating score of 4 and above indicated that the sample was favoured by the panellists) while pasta containing 15% OMF was not preferred by panellists, as shown by its scores, the lowest of the samples for all attributes.

Sensory evaluation studies demonstrated that there were no significant differences for control pasta as compared to pasta with 5% OMF for all attributes. Similarly, pasta with 10% OMF was found to be comparable with the control pasta in almost all attributes except for colour. This might be due to the fact that the colour of OMF was moderately dark, with a slight combination of red and yellow. This finding agrees with a study conducted using OMF in biscuit formulation (Ng *et al*., 2017).

In addition, the results also revealed that for

Table 4. Sensory analysis of pasta formulated with different levels of OMF.

Sensory parameter	Levels of OMF incorporation (%)			
	0	5	10	15
Appearance	4.92 ± 0.19	5.08 ± 0.15	4.45 ± 0.13[d]	3.67 ± 0.16[c,f,h]
Aroma	4.13 ± 0.21	4.08 ± 0.16	4.13 ± 0.15	3.73 ± 0.16
Colour	5.07 ± 0.17	4.88 ± 0.14	4.32 ± 0.15[b,d]	3.38 ± 0.14[c,f,i]
Flavour	3.80 ± 0.20	4.03 ± 0.17	4.18 ± 0.16	3.70 ± 0.21
Texture	4.57 ± 0.17	4.75 ± 0.16	4.65 ± 0.15	3.88 ± 0.18[a,e,h]
Aftertaste	4.35 ± 0.20	4.35 ± 0.16	4.10 ± 0.18	3.82 ± 0.19
Overall acceptance	4.52 ± 0.18	4.58 ± 0.16	4.42 ± 0.15	3.80 ± 0.17[a,e,g]

a = $p < 0.05$; b = p < 0.01; c = $p < 0.0001$ compared to 0% OMF pasta; d = $p < 0.05$; e = p < 0.01; f = $p < 0.0001$ compared to 5% OMF pasta; g = $p < 0.05$; h = p < 0.01; i = $p < 0.001$ compared to 10% OMF pasta.

some attributes, such as flavour and texture, the mean scores of the pasta with 10% OMF were higher as compared to the control pasta. The flavour of the pasta was enhanced by the incorporation of OMF, which provided this pasta with a typical, pleasant, oyster mushroom flavour. Therefore, it can be suggested that the flavour and texture acceptance of pasta could be improved by adding up to 10% OMF.

In contrast, the pasta formulated with 15% OMF had significantly lower scores for most attributes as compared to the control and the 10% OMF formulation. The statistical analysis showed that, with higher amounts of OMF added, undesirable results were obtained in the pasta. It was shown that 15% OMF in the pasta demonstrated notably impaired appearance, colour, and texture, whereby, it possessed a darker colour and a less firm texture. This might be due to the fact that the colour of OMF was moderately dark and that decreased values of firmness exist with increased levels of OMF, as discussed earlier. Even though the 15% OMF pasta was not accepted by the panellists overall, attributes like aroma, flavour, and aftertaste were still found to be comparable with the other samples.

This finding aligned with a study conducted by Aishah (2013), who found that panellists preferred lower percentages of OMF used in the creaming cake formulation. In a previous study, Prabhasankar *et al*. (2009) observed that pasta samples comprised of up to 10% seaweed powder had greater acceptance scores from the panellists. On the other hand, in the other samples where the seaweed content was increased beyond 10%, sensory scores were reduced significantly as compared to control. Yet, other findings in which pasta was fortified with up to a 10% substitution of lupin flour (Torres *et al*., 2007a), chickpea flour (Wood, 2009), or germinated pigeon pea flours (Torres *et al*., 2007b) were generally well accepted. Therefore, it was concluded that up to a 10% OMF level was better both in terms of sensory attributes and additional nutritional quality.

Conclusion

OMF fortification could possibly be used for the partial substitution of wheat flour in pasta production because of its ability to improve the nutritional quality of the original food product without ignoring the palatability aspects. Oyster mushrooms are considered a sub-product of little commercial value and an insignificant industrial advantage; so, for oyster mushroom growers as well as pasta and tortilla product makers, this represents a possibility of diversifying and expanding their markets. An addition of 10% OMF in the pasta formulation was found to increase nutritional values, affecting some physicochemical properties while improving the sensorial attributes of flavour and texture.

Acknowledgement

The authors would like to acknowledge the Ministry of Education of Malaysia for providing a scholarship under the MyBrain15 Programme, and the School of Health Sciences, Universiti Sains Malaysia for providing the research facilities.

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