

Does oyster mushroom (*Pleurotus sajorcaju*) powder addition improve nutrient composition, sensory acceptability, and glycaemic index (GI) of flatbread (Tortilla)?

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Abstract

Regular consumption of dietary fibre (DF) has been proven to reduce the risk of non-communicable diseases, which leads to the rising demand for DF-enriched products. The study aims to investigate the effect of *Pleurotus sajorcaju* powder (PSP) incorporation on the nutrient composition, sensorial acceptability, and glycaemic index (GI) of the developed tortilla. Four tortilla formulations with different PSP levels (0%, 5%, 10%, and 15%) to replace wheat flour partially were prepared. The control tortilla's protein concentration was 8.26% and increased to 9.31, 9.72, and 10.60% when incorporated with 5, 10, and 15% PSP, respectively. Both the 10% and 15% PSP tortilla (12.00% and 13.62%) were found to be significantly higher than the control tortilla in total DF. The β -glucan content was the highest in the tortilla with 15% PSP added (1.21%). In sensory evaluation, the tortilla fortified up to 15% PSP was apparently well accepted by the sensory panelists. Control tortilla had an intermediate GI value (58) while 15% PSP tortilla had a low GI value (53). In summary, adding up to 15% PSP in the tortilla formulation increased nutritional values, improved sensorial attributes, and reduced GI value.

Keywords: Glycaemic index (GI); nutrient; *Pleurotus sajorcaju*; sensory evaluation; tortilla.

1. Introduction

Presently, the prevalence of non-communicable diseases (NCDs) is rising at a remarkable rate and becoming a main public health issue throughout the world, including Malaysia. The NCDs include cancers, chronic respiratory diseases, cardiovascular diseases, and type 2 diabetes mellitus (T2DM) are the main factors of fatality in the world (Zheng *et al.*, 2018). The prevalence of NCDs is increasing swiftly and is predicted to

exceed as the common causes of mortality by 2030 (Zheng *et al.*, 2018). The increased NCDs rate is proportionally associated with the low intake of DF in individuals' daily meals or diets. DF is an important nutrient in our staple diets and naturally exists in nuts, cereals, fruits, vegetables (Dhingra *et al.*, 2012), and fungi (Ng *et al.*, 2017). Sufficient daily intake of DF has been scientifically proven to decrease certain NCDs' risks such as colorectal cancer, cardiovascular diseases, diabetes, and obesity (Lattimer *et al.*, 2010; Jochem & Leitzmann, 2016).

Among many types of edible fungi, oyster mushrooms (*Pleurotus spp.*) have commonly been consumed. This natural food item shows an excellent taste and contains a significant nutrient component concentration, including carbohydrates, proteins, minerals, and vitamins. Besides, numerous research outcome has revealed that oyster mushrooms can reduce and prevent several severe diseases, including cholesterol and hypertension (Agrawal *et al.*, 2010), prostate cancer and breast cancer (Jedinak & Sliva, 2008). β -glucan is a main bioactive compound that commonly exists in oyster mushrooms, is linked with lowering the glycaemic response and blood cholesterol levels *in vivo* (Zhu *et al.*, 2015). The dried oyster mushroom is high in β -glucan (3.32-25.83%) and total DF (33.00-56.99%) content (Ng *et al.*, 2017). Moreover, the incorporation of PSP to partially replace wheat flour in a flatbread such as a tortilla is intended to improve nutrient composition since PSP contains a significant amount of β -glucan, DFs, and protein, as reported by Ng *et al.*, 2016.

Tortillas are unleavened flatbreads or pancakes made from either corn or wheat flour. It can be used as a substitute for bread and snacks and serve as a principal meal of the human daily diet. Currently, great interest has been created in the development and consumption of tortillas enhanced with numerous nutritive ingredients such as amaranth flour, flaxseed flour, triticale flour, black bean, and soybean (Islas-Hernandez *et al.*, 2007; Rendon-Villalobos *et al.*, 2009; Vaca-Garcia *et al.*, 2011; Grajales-Garcia *et al.*, 2012; Obatolu *et al.*, 2007). Similar to white bread, wheat-based flour tortillas are rich in carbohydrates that produce a high glycaemic response after consumption (Saldana & Brown, 1984). Therefore, the current study aimed to evaluate the effect of substituting wheat flour with different PSP levels for tortillas production and its effect on

nutrient compositions, sensorial acceptability, and GI values.

2. Material and Methods

Oyster mushrooms (*Pleurotus sajorcaju*, PS) grown on a sawdust substrate were utilized in the present study. Clusters of PS, grown within 6-8 d after spawning, were harvested by using sterile scissors so that no extra mushroom mycelium would be teased. Exactly, 5 kg harvested mushrooms were dehydrated using the low-heat air-dried drying technique at 50-55° for 2 hrs, established by Anjaad Industries (M) Sdn. Bhd. The dehydrated PSP (yield approximately 10% w/w) was milled into powder using an electric grinder (Waring Commercial 8010S, USA) and sifted into a fine powder using a sieve with a mesh diameter of 125 μ m. The collected PSP was then kept in screw cap bottles and stored at 4°C until further use.

2.1. Development of Tortilla

The tortilla was produced in a flatbread shape, adapted from Anton *et al.*, 2008, with a slight modification on the ingredients' composition used. The original ingredient of wheat flour was added with PSP at 5%, 10%, and 15%. These PSP-based tortillas were compared with a control tortilla, which was made of 100% wheat flour (0% PSP). Firstly, the all-purpose flour was thoroughly mixed with PSP, vegetable fat, baking powder, and salt in a mixing bowl. Then, water was added to the mixture, and then the dough was mixed manually. Next, the mixture was cut into uniformed pieces of 35 g. After that, the dough was manually rounded and allowed to rest for 30 min for proper hydration. After resting, each ball was then stretched using a baked roller to form a round shape. The flat doughs were cooked on a hot non-stick pan for 1 min per side (Model KX-11K1, Sharp Corporation, Japan). Finally, the cooked tortillas were cooled on a rack for 1 min and

packed in four polyethylene plastic bags according to formulations prior to analyses. While waiting for further analyses, the tortillas were sealed after 3 h and labelled in four different air-tight plastic containers according to their formulations.

2.2. Analyses of the nutrient composition

Tortilla samples were analysed for ash, moisture, fat, protein, and total DF according to the standard analytical method (AOAC, 2000). The tortillas' β -glucan levels were quantified according to the AOAC, 2000, using a Mixed-Linkage β -glucan Test Kit (Megazyme International Ireland Ltd., Ireland). The tortillas' carbohydrate contents were determined by calculating the percent remaining after all the other components (by difference method). The following formula determined the calorie (kcal/100 g) value of the samples: Carbohydrate: 1 g = 4 cal; Fat: 1 g = 9 cal and Protein: 1 g = 4 cal.

2.3. Color properties

The sample color 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 color was measured using the L*, a*, b* scales as lightness (white to black), yellowness (yellow to blue), and redness (red to green) indications, respectively.

2.4. Sensory evaluation

Cooked tortilla 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 tortilla formulations were served to each panelist individually. The panelists were asked to indicate the aroma, appearance,

color, texture, flavor, aftertaste, and overall acceptability for all samples. A seven-point hedonic rating scale, where 1 corresponded to 'dislike the most', 4 to 'moderately like', and 7 to 'like the most' was used to determine each attribute (Aminah *et al.*, 2000).

2.5. Glycaemic index (GI) determination

Fourteen healthy human subjects (three males and eleven females) were randomly selected from staffs and students of Universiti Sains Malaysia, Healthy Campus. The criteria were: age between 18 to 65 years; body mass index (BMI) of 18.5 to 25 kg/m². Ethical clearance for this study was approved by the Research Ethics Committee (Human) of Universiti Sains Malaysia. Subjects were served with 25 g available carbohydrate portions of the reference food and the test foods (FAO/WHO, 1998). The fingertip capillary blood samples (5 μ L) were collected at fasting, then repeatedly at 15, 30, 45, 60, 90, and 120 minutes after consuming the test food. The test meals were served with drinking water (250 ml) in each session. Determination of incremental area under the curve (iAUC) was calculated using Microsoft Excel (Version 2007, USA), in which the trapezoid rule was applied. Only the area above the fasting level was included if the blood glucose response value falls below the baseline. The GI of the test foods was then calculated according to FAO/WHO, 1998.

2.6. Statistical analysis

Statistical analyses were performed using the GraphPad Prism Software (Version 6.01, USA). The results were expressed as the mean \pm 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 $p = 0.05$.

3. Results and discussion

3.1. Nutrients composition

Generally, all components were found to increase proportionally with the PSP level added into the tortilla formulations except for moisture and carbohydrates, which decreased with increasing PSP levels (Table 1). The moisture contents of both the PSP and wheat flour, which were pre-determined before mixing, were 8.84% and 11.00%, respectively. The tortilla's moisture contents with PSP incorporated ranged from 16.12 to 19.07%, while the tortilla without PSP contained more moisture (19.50%). In the present study, the moisture content was decreased with the increased levels of PSP. Decreased values of moisture content have also been reported by Islas-Hernandez *et al.*, 2007, in corn tortillas with added amaranth flour and flaxseed (Rendon-Villalobos *et al.*, 2009). The dried oyster mushrooms naturally possess water holding capacity and low water content, and this might have caused the lower moisture content detected in the tortilla with added PSP. Moreover, the sugars, starch, and DF that exist in dried PSP might haven't contributed, as they can contain a small amount of water (Mohamed *et al.*, 2010). Concurrently, other findings reported that PSP-enriched cookies contained lower moisture contents than control cookies (Ng *et al.*, 2017). Cookies are considered very low-moisture-content products, as the thermal processing brings down the final moisture content (ranging from 2 to 5%) in the food product. On the contrary, increased moisture content values have been documented by Aishah & Wan Rosli, 2013, in shortened cakes with added PSP. The difference in moisture content is due to the fact that the present study used different types of ingredients and composition and cooking

techniques as compared to Aishah & Wan Rosli, 2013.

Table 1. Nutritional composition of tortilla (g/100 g) added with PSP.

Component (%)	Levels of PSP incorporation (%)			
	0	5	10	15
Moisture	19.50 ±0.10	19.07 ±0.04 ^b	16.71±0. 05 ^{cg}	16.1± 0.04 ^{gi}
Total ash	0.66± 0.01	0.84± 0.03 ^b	0.98± 0.03 ^{cd}	1.14± 0.03 ^{eh}
Crude fat	5.60± 0.08	5.73± 0.07	6.65± 0.04 ^{cg}	7.60± 0.05 ^{cgk}
Protein	8.26± 0.21	9.3± 0.08 ^a	9.72± 0.28 ^b	10.6± 0.06 ^{eh}
Carbohydrate	65.9± 0.18	65.05± 0.17 ^a	65.94 ± 0.21 ^d	64.55± 0.14 ^{bi}
Total dietary fibre	9.31± 0.07	9.99± 0.00	12.00± 0.67 ^a	13.62± 0.39 ^{be}
Beta-glucan	0.69± 0.03	1.02± 0.03	1.05 ± 0.20	1.21 ± 0.17
Calorie (kcal/100g)	365.99± 0.78	368.99 ± 0.40	386.45 ± 0.81	396.21 ± 0.51

a=p<0.05; b=p<0.01; c=p<0.0001 compared to 0% PSP tortilla; d=p<0.05; e=p<0.01; f=p<0.001; g=p<0.0001 compared to 5% PSP tortilla, h=p<0.05; i=p<0.01; j=p<0.001; k=p<0.0001 compared to 10% PSP tortilla

The concentration of the total ash significantly increased with increasing PSP levels in the tortilla formulation. The control tortilla contained 0.66% total ash, while the tortilla formulations with 5%, 10%, and 15% PSP were recorded as having 0.84, 0.98, and 1.14% total ash, respectively. In agreement with other studies' results, total ash increments were also observed in cookies (Ng *et al.*, 2017) and shortened cakes (Aishah, 2013) added with PSP. Similar findings were also obtained for tortillas made with a blend of quality protein maize and black bean (Grajales-Garcia *et al.*, 2012), home-made maize tortilla with soybean (Obatolu *et al.*, 2007), and paratha bread added with PSP

(Aishah & Wan Rosli, 2013). From a nutrition science standpoint, PSP could improve the tortilla's mineral contents; this is supported by the findings obtained in the present work, which indicated that the ash contents in the tortilla increased with increasing PSP levels.

Fat contents ranged from 5.73 to 7.60% in the tortilla with PSP incorporated, while the control tortilla contained less fat (5.60%). The tortilla added with 5% PSP had 5.73% of fat but not significantly as compared to the control sample. On the other hand, 10 and 15% PSP tortillas recorded 6.65 and 7.60% of crude fat, respectively, and significantly higher than the control sample. In accordance with the findings of other studies, the increments of fat were also observed for tortillas made with different pigmented varieties of corn (Islas-Hernandez *et al.*, 2007, and tortilla prepared with chia seeds (Rendon-Villalobos *et al.*, 2012).

An increment of protein content in the tortilla was found in line with the PSP level used to replace the wheat flour partially. The control tortilla's protein concentration was 8.26% and increased to 9.31, 9.72, and 10.60% when incorporated with 5, 10, and 15% PSP, respectively. The protein content of PSP-based tortillas was significantly higher than the control tortilla. Tortilla added with 15% PSP contain a significantly higher protein amount than 5 and 10% PSP tortillas. However, there was no significant difference between 5 and 10% PSP tortillas in protein content. The increase in the protein content in PSP-added tortilla might be important to increase the essential amino acid level that is deficient in wheat flour. This showed that the nutrient content of the tortilla substituted with PSP was better than the control tortilla. This might be due to the fact that the PSP used in the present work had a significant amount of protein, ranging between 21.01 to 22.41%. Similar findings related to the increased values of protein in tortilla were also

observed in other studies (tortilla formulated with amaranth flour (Islas-Hernandez *et al.*, 2007), flaxseed flour (Rendon-Villalobos *et al.*, 2008), black bean (Grajales-Garcia *et al.*, 2012), maize-bean flour (Hernandez-Salazar *et al.*, 2006), bean flour (Anton *et al.*, 2008).

The carbohydrate contents in the tortilla were found to decrease with increasing PSP levels slightly. The carbohydrate content of the control tortilla (65.98%) did not differ significantly with the addition of 5%, 10%, and 15% PSP, which resulted in 65.05%, 65.94%, and 64.55% carbohydrates. A similar finding was presented by Ng *et al.*, 2017, who fortified cookies with PSP. The present results were also in accordance to the study performed by Obatolu *et al.*, 2007, and Rendon-Villalobos *et al.*, 2008, who found a decreased in carbohydrate contents when the increased levels of soybean and flaxseed incorporated in the tortilla. However, in another study, Aishah & Wan Rosli, 2013, documented that carbohydrate contents increased when PSP was incorporated in shortened cakes, although this might be due to the shortened cakes' different formulations.

The TDF contents in the tortilla with PSP incorporated ranged from 9.99% to 13.62%, while the control tortilla contained less TDF (9.31%). Both the 10% and 15% PSP tortilla (12.00% and 13.62% TDF) were found to be significantly higher than the control tortilla in TDF. This finding could be attributed to the natural TDF concentration contributed by the PSP. Hence, this result signifies that PSP could be potentially considered as an alternative food ingredient to improve the TDF content of tortillas and other processed food products. Earlier studies performed by Ng *et al.*, 2017, and Aishah, & Wan Rosli, 2013, also found that the incorporation of PSP increased the TDF content. Also, Torres *et al.*, 2007, and Prabhasankar *et al.*, 2009, reported that TDF contents were increased

when wheat flours were replaced in germinated *Cajanus cajan* seeds and different types of seaweeds in their products. The DF assists manage peristalsis (promoting bowel motion), and the slowing of peristalsis leads to constipation. Besides the discomfort it can bring, constipation has been linked with a range of illnesses and disorders, including varicose veins. The DF is also a good binder of toxicants as well as certain nutrients in foods. Even though toxicants' entrapment can protect the body, excess fibre intake may limit the absorption of some essential minerals and vitamins (Shewfelt, 2009). Previously, both studies conducted by Rendon-Villalobos *et al.*, 2009, and Grajales-Garcia *et al.*, 2012, have shown the improvement of TDF in tortilla incorporated with flaxseed and a blend of maize and black bean.

3.2. β -glucan content

Among all formulations, the β -glucan content was the highest in the tortilla with 15% PSP added (1.21%). The results showed that the 15% PSP tortilla had significantly higher β -glucan than the control and the 5% PSP tortilla (Table 1). Previously, linearly increasing levels of β -glucan contents have also been reported with increasing PSP levels substituted in cookies (Ng *et al.*, 2017) and shortened cakes (Aishah and Wan Rosli, 2013). Dried oyster mushrooms have been considered a functional food due to their nutritional and medicinal characteristics that are associatable with the existence of β -glucan. They have exhibited significant beneficial health effects, such as an anti-tumour nature, hypocholesterolaemia, and immunomodulatory activities (Kim *et al.*, 2011; Samsudin and Abdullah, 2019).

3.3. Calorific value (kcal/100 g)

The tortilla's calorific values were found to increase with increasing PSP levels even

though these were not significant. Increasing the PSP levels in the tortilla formulations resulted in increasing the calorific value by 0.8-8.0% (Table 1). This finding was in agreement with Torres *et al.*, 2007, who observed that spaghetti supplemented with germinated pigeon pea flour showed an increase in the caloric value (358.19 kcal/100 g) when compared with control spaghetti (320 kcal/100 g).

3.4. Color properties

In general, redness (a^*) and yellowness (b^*) attributes were significantly higher with increasing PSP levels, but lightness (L^*) was significantly lower with increasing PSP levels (Table 2). The incorporation of PSP into the tortilla formulations resulted in lower L^* values as compared to the control tortilla; the lightness of the tortilla with PSP added at several levels (5%, 10%, and 15%) was detected between 57.47 to 65.18 L^* values while the control tortilla had a 76.09 lightness intensity. Another study also found out that L^* value increased significantly when ground oyster mushroom was added at different levels in herbal seasoning products (Saiful Bahri, 2015). The substitution of PSP into the tortilla formulations resulted in higher a^* values than the control tortilla. Redness in the tortilla with 0%, 5%, 10%, and 15% PSP levels was recorded at -1.17, 2.75, 4.12 and 5.68 a^* values, respectively. Concurrently, increased a^* value have also been observed when herbal seasoning product was incorporated with different levels of ground oyster mushroom (Saiful Bahri, 2015). On the other hand, a study by Ng *et al.*, 2017, regarding PSP-enriched cookies reported 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. Effect of PSP on color of tortilla.

Scales	Levels of PSP incorporation (%)			
	0	5	10	15
L^*	76.09 ± 0.01	65.18 \pm 0.03 ^a	63.44 \pm 0.01 ^{ac}	57.47 \pm 0.01 ^{acd}
a^*	-1.17 \pm 0.01	2.75 \pm 0.0 ^a	4.12 \pm 0.01 ^{ac}	5.68 \pm 0.01 ^{acd}
b^*	21.75 ± 0.01	22.71 \pm 0.02 ^a	22.81 ± 0.0 ^{ab}	24.15 \pm 0.0 ^{acd}

a= $p < 0.0001$ compared to 0% PSP tortilla,
b= $p < 0.001$; c= $p < 0.0001$ compared to 5%
PSP tortilla

d= $p < 0.0001$ compared to 10% PSP tortilla

3.5. Sensory acceptability

Tortilla fortified with up to a 15% PSP substitution was generally well accepted (Table 3). A rating score of 4 and above indicated that the panelists favored the sample (Nordiana *et al.*, 2019). Sensory evaluation studies demonstrated that there were no significant differences for control tortilla as compared to pasta with 5% PSP for all attributes. In fact, PSP-based tortillas were found to receive higher scores for aroma, color, and flavor than control tortilla. In this study, the 5% and 10% PSP tortillas score were significantly higher than the control tortilla in all attributes except for aftertaste. Also, 5% PSP tortilla scored the highest values for all sensory attributes. Tortilla incorporated with 10 and 15% PSP were found to be comparable with control tortilla (0% PSP) in all attributes except for aftertaste and appearance. The current result demonstrates that panels prefer tortilla sample, which contains up to 15% of PSP for all attributes (the score values range from 4.00 to 4.54). In fact, the control sample has the lowest scores for aroma, color, flavor, and texture. The tortilla's flavor was enhanced by incorporating PSP, which provided this tortilla with a typical, pleasant oyster

mushroom flavor. Therefore, it can be suggested that the flavor and texture acceptance of tortilla could be improved by adding up to 10% and 15% PSP. According to Obatolu *et al.*, 2007, soybean's addition did not significantly affect the tortilla's overall acceptability. Likewise, bean tortillas' overall acceptability was significantly higher than the wheat control (Anton *et al.*, 2009). Even though the sensory scores of tortillas added with 10% are relatively higher than 15% PSP-tortilla for all attributes, it was not significant. This value (15% PSP level) was chosen for GI determination since the higher the DF value, the higher the product's tendency to have a low GI value (Ng *et al.*, 2017).

Table 3. Sensory analysis values of tortillas added with different levels of PSP.

Attributes	Levels of PSP incorporation (%)			
	0	5	10	15
Appearance	4.02 ± 0.21	4.75 \pm 0.16 ^a	4.56 \pm 0.15	4.00 \pm 0.18 ^d
Aroma	3.53 \pm 0.18	4.54 \pm 0.15 ^c	4.32 \pm 0.16 ^b	4.54 \pm 0.17 ^c
Colour	3.97 \pm 0.18	4.93 \pm 0.16 ^c	4.44 \pm 0.15	4.37 \pm 0.18
Flavour	3.95 \pm 0.19	4.73 \pm 0.17 ^a	4.19 \pm 0.17	4.20 \pm 0.19
Texture	4.31 \pm 0.17	4.66 \pm 0.15	4.44 \pm 0.15	4.39 \pm 0.17
Aftertaste	4.39 \pm 0.17	4.80 \pm 0.17	4.36 \pm 0.17	4.09 \pm 0.19 ^d
Overall acceptance	4.34 \pm 0.16	4.90 \pm 0.15	4.46 \pm 0.16	4.32 \pm 0.17

a= $p < 0.05$; b= $p < 0.01$; c= $p < 0.001$ compared to 0% PSP tortilla; d = $p < 0.05$ compared to 5% PSP tortilla.

3.6. The GI Value of Tortilla

The GI is a measure of the potential of a carbohydrate-containing food to elevate blood glucose concentration after ingestion. The GI and iAUC values of the tortilla formulated with PSF and reference glucose are shown in Table 4. Control tortilla had an intermediate GI value (58) while 15% PSP tortilla had a low GI (53). Tortilla added with 15% PSP revealed a small reduction in GI compared to control tortilla. However, this decrement was not significant. These outcomes propose that intestinal glucose release after ingestion of PSP-added tortilla might be lesser than when the control tortilla was ingested. Another possible explanation is that the higher DF content occurred in 15% PSP tortilla (13.62%) than 9.31% in the control tortilla as described previously in Table 2. The increased amount of total DF in 15% PSP tortilla might be accountable for developing a polysaccharide linkage that can capture the starch granules during processing. The entrapment of starch decreases availability to enzymatic degradation, and consequently, decreases the sugars released in the blood (Foschia *et al.*, 2015). Besides, the higher protein content also can be accountable (10.60% in 15% PSP tortilla compared to 8.26% in control tortilla). It was formerly stated that the existence of protein in the food matrix affects the degree of starch breakdown (Kim *et al.*, 2008). The higher amount of protein probably builds a tougher network, therefore decreasing the starch accessibility to enzymatic attack.

Table 4. Glucose response (iAUC) and GI values of tortilla (n=14)

Test food	iAUC (mmol x min/l)	GI
0% PSP tortilla	119 ± 17 ^a	58 ± 8 ^b
15% PSP tortilla	106 ± 11 ^b	53 ± 5 ^b
Glucose	201 ± 9	100

a = p<0.001; b = p<0.0001 compared to glucose

Moreover, another explanation can be due to higher β -glucan content (1.21% in 15% PSP tortilla compared to 0.69% in control tortilla). The useful properties of β -glucans have been recognized by their capability to increase lumen viscosity (Dikeman & Fahey, 2006; Wood, 2002). It has been advocated that β -glucan, by increasing the viscosity of the gastrointestinal tract contents, interrupts gastric emptying and the intestinal absorption of nutrients like digestible carbohydrates and thus decreases postprandial glycemia and insulin excretion (Lazaridou & Biliaderis, 2007). This might be suggested that the helpful action of β -glucan is mostly because of delayed and reduced carbohydrate absorption from the gut and does not result from the effects of metabolites formed by fermentation of β -glucan in the colon. It is also possible that β -glucan not only declines the postprandial glucose response (GR) in the gastrointestinal tract due to high viscosity but also decreases starch breakdown by α -amylase (Lazaridou & Biliaderis, 2007). A former study indicated that the incorporation of 0, 2, 4, and 8 g of barley β -glucan in a 75 g glucose drink reduced postprandial glucose and insulin levels in a dose-dependent manner (Panahi *et al.*, 2005). Vitaglione *et al.*, 2009, found out that using 3% of β -glucan from Glucagel significantly reduced (9% less) the glucose response of bread.

Generally, the changes in the level of nutritional composition and the GI decline show that the incorporation of PSP in the mixture plays the most major role in the overall starch digestibility. Low GI carbohydrates are usually considered to be food with GI values of 55 and below. Foods that have a GI between 56 and 69 are considered to have a moderate GR, and those GI values 70 and above have a high GR. Similarly, in a study done by Grajales-García *et al.*, 2012, found out that the incorporation

of bean reduced the predicted GI (pGI) value of tortilla (79.8) that was higher (88) in maize tortilla. Also, Rendon-Villalobos *et al.*, 2008, observed that the control sample (common white tortilla) exhibited a pGI of 101, and those tortillas fortified with flaxseed flour had much lower pGI values (73–88). In another study, fresh white corn tortilla had a pGI of 97.5, but blue corn tortillas' value was significantly lower (85.8) (Hernandez-Uribe *et al.*, 2007). Contradictorily, Islas-Hernandez *et al.*, 2007, observed that amaranth-containing tortilla showed higher pGI (107) than corn tortilla (control) (103).

There was no significant difference between iAUC of control tortilla and 15% PSP tortilla (Figure 1). On the other hand, the iAUC and GI values of 0 and 15% PSP tortillas were significantly lower than those of glucose. For both test foods, the blood glucose levels (BGLs) were significantly lesser at 15, 30, 45, and 60 min. At 0, 90, and 120 min, there was no significant difference of BGLs between glucose and two test foods (0 and 15% PSP tortillas). Moreover, the peak BGLs have reached a maximum at 45 min for the glucose and test foods. Besides, the BGLs also began to gradually decline after 45 min for all samples.

4. Conclusion

Fortification of PSP could possibly be used for the partial substitution of wheat flour in tortilla 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 and tortilla product makers, this represents a possibility of diversifying and expanding their markets.

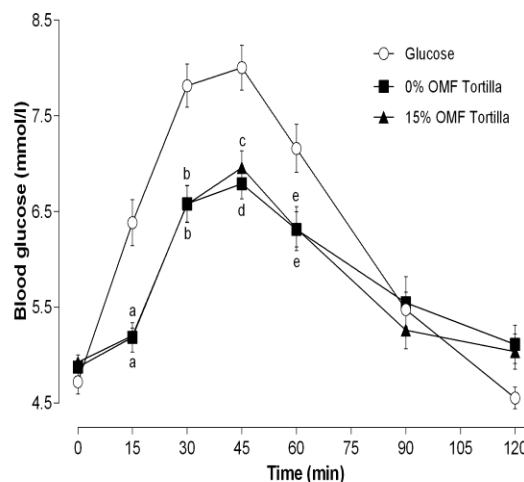


Fig. 1. BGLs in response to the addition of 0% and 15% PSP in tortilla.

a= $p < 0.0001$ compared to glucose at 15 min; b= $p < 0.001$ compared to glucose at 30 min; c= $p < 0.01$; d= $p < 0.001$ compared to glucose at 45 min, e= $p < 0.05$ compared to glucose at 60 min; Glucose represent glucose drink as control.

An addition of 15% PSP in the tortilla formulation was found to increase nutritional values, affect color properties, improve sensorial attributes, and reduce GI value.

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