Instrumental texture and sensory preference of vacuum-fried shiitake crisps as affected by isomalto-oligosaccharide pretreatment

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ABSTRACT

Shiitake (Lentinula edodes) is well-known for its distinct flavor and texture as well as its medicinal and nutritional properties. Small good grade fresh shiitake mushrooms are highly perishable and have a low commodity value in the Taiwan market. As a result, these are frequently used as raw materials for vacuum-fried crisps. However, manufacturers continue to use traditional maltose (MO) syrup with no functional properties as a sweetener, and shiitake stipes are frequently discarded, increasing production costs. Isomalto-oligosaccharide (IMO) is a functional oligosaccharide sweetener with health benefits. The purpose of this research is to study the use of functional IMO in the processing of shiitake crisps to replace MO, and the reusability of stipes. In the manufacture of vacuum-fried shiitake cap and stipe crisps, the 30–40°Brix IMO syrup replaces the 35°Brix MO syrup. Vacuum-fried crisps’ quality characteristics were determined using physicochemical and sensory evaluation. The results showed that centrifuged caps and stipes reach equilibrium after 3 h of being soaked in various concentrations of 90–95°C syrup. The \( L^* \), \( a^* \), \( b^* \), and \( c^* \) values for the cap crisps decreased with the increase in the level of IMO syrup. The breaking force for the stipe crisps was less than that for cap crisps. The crude protein and crude fat content of vacuum-fried cap and stipe crisps decreased as the level of IMO syrup increased, but the carbohydrate content increased. For a nine-point hedonic test, the sensory scores for cap and stipe crisps without seasoning powder were 6.9–7.4 and 6.1–6.5, respectively. Addition of seasoning powder increased the flavor and overall scores to 8.1–8.2 and 7.2–7.4, respectively. Overall, the addition of IMO syrup reduced the calories and increased the health benefits of vacuum-fried shiitake crisps. Furthermore, the result showed that stipes can also be used to make vacuum-fried crisps and increase profitability for manufacturers.

Introduction

Lentinula edodes, also known as xianggu in Chinese and shiitake in Japanese, is a medicinal and edible mushroom native to East Asia. It is well-known for its distinct flavor and texture, as well as its medicinal and nutritional properties. In Taiwan, fresh shiitake is classified as special, premium, or good and comes in three sizes determined by the diameter of the caps: small (3–5 cm), medium (5–7 cm), and large (>7 cm). Fresh, small, good grade shiitake are highly perishable and have a low...
commodity value in the market, so they are often used as raw materials for processed mushrooms, such as vacuum-fried crisps.

Vacuum frying is a food processing technique that uses low pressure and temperature to dry food rather than atmospheric deep-fat frying to improve the quality of fried products. The vacuum-fried product has a special flavor and texture, and the oil content is lower than that of conventional atmospheric deep-fat-fried products.\[3\] The quality of products can be reduced during the vacuum frying process. Many studies have been conducted to determine the effect of pretreatment methods (such as blanching, pre-drying, osmotic dehydration pretreatment, coating, and freezing) on the quality of vacuum-fried foods to improve product quality.\[2,4,5\] Vacuum-fried shiitake crisps are a type of snack that makes use of vacuum-frying technology. They are popular because they are crunchy, crispy, and have a fragrant aroma. However, there are several opportunities for improvement. Manufacturers, in particular, continue to use traditional maltose (MO) syrup, which has no functional properties as a sweetener, and stipes are not used, increasing production costs.

Isomalto-oligosaccharide (IMO) is a health-promoting functional sweetener found naturally in honey and a variety of fermented foods such as miso, sake, and soy sauce. As IMO is mainly composed of α-D-glucose residues linked by α-(1→6) glycosidic bonds, it is slowly digested in the jejunum and can be fermented by intestinal flora.\[6\] Currently, IMO is made by hydrolyzing starch with enzymes such as α-amylase and β-amylase, which produce maltose, which is then converted to IMO through transglucosylation of α-glucosidase.\[7\]

Many studies show that IMO has positive functional properties, such as a proliferation of bifidobacteria,\[8,9\] its positive effect on constipation,\[10–12\] reduction of fecal putrefactive metabolites such as indole and p-cresol,\[11,13\] reduction of serum total cholesterol and triglyceride,\[12–14\] as well as the prevention of dental caries.\[15\] IMO is a type of functional oligosaccharide syrup that is used as a functional sweetener in Taiwan and Japan, making it a useful ingredient in functional vacuum-fried shiitake crisps.

To the best of the authors’ knowledge, no relevant research on the effect of IMO on the quality characteristics of vacuum-fried mushrooms exists. This study uses small, good grade, fresh shiitake as a raw material to determine the effect of various concentrations of IMO syrup on the quality characteristics of vacuum-fried shiitake cap and stipe crisps.

**MATERIALS AND METHODS**

**Materials and chemicals**

Small, good grade fresh shiitake was purchased from a mushroom farm in Puli, Nantou, Taiwan. After harvesting, the shiitake mushrooms were packed in polyethylene bags and transported to Hungkuang University in a refrigerated truck (4–7°C). IMO syrup (24.7% water) was purchased from Taiwan Fructose Co. (Taoyuan, Taiwan). The MO syrup (24.5% water) was purchased from Zhengyu Malt Factory (Tainan, Taiwan). The sugar content of IMO and MO syrup was determined by high performance liquid chromatography. The IMO (Isomaltose + Panose + Isomaltotriose + Isomaltotetraose) content (g/100 g dry matter) of IMO syrup is 58.6. Vegetable frying oil containing refined oils of palm olein and palm stearin, and L-ascorbyl palmitate was purchased from Namchow Oil and Fat Co. (Taipei, Taiwan). Seasoning powder containing salt, nucleotides, and maltodextrin was purchased from Gemfont Co. (Taipei, Taiwan).

All sugar standards were purchased from Sigma-Aldrich (St. Louis, MO, USA). Acetonitrile was purchased from Avantor Performance Materials (Randor, PA, USA). Hexane was purchased from Tedia (Fairfield, OH, USA). Cupric sulfate and sodium hydroxide were purchased from Shimakyu Pure Chemicals (Osaka, Japan). Potassium sulfate was purchased from Nihon Shiyaku Reagent (Tokyo, Japan). Methyl red pure was purchased from Koch Light Research Laboratories (Gauteng, South Africa) and methylene blue purchased from Katayama Chemical Industries (Osaka, Japan).
**Preparation of vacuum-fried shiitake crisps**

Fresh whole shiitake were separated into caps and stipes using scissors. After washing (30 s in running water), the caps and stipes were blanched in boiling water with a shiitake to water ratio of 1:5 (w/w) for 5 min. The blanched caps and stipes were immediately immersed in an ice bath to cool for 1.5 min. After draining for 1 min, the blanched samples were placed in plastic baskets and frozen at −25°C for 24 h in a freezer. The frozen shiitake were then placed in a refrigerator at 4–7°C to defrost.

The thawed shiitake were centrifuged in a stainless steel centrifugal separator at 1400 rpm for 2 min and then soaked in various concentrations of 90–95°C syrup, including 35°Brix MO syrup (control), 30° Brix, 35°Brix and 40 °Brix IMO syrup. The respective ratio of the centrifuged caps and stipes to syrup were 1:1 and 1:1.3 (w/w) and the sugaring time was 1–6 h. The candied shiitake was soaked for 3 h before being fried for 90 min in a vacuum fryer (Model NO 1-FK, Fulco Machinery Co., Ltd., Yunlin, Taiwan) at 95 ± 2°C in a vacuum of 68–72 cm-Hg. It was then centrifuged at 250 rpm for 20 min.

The partially defatted samples were sprinkled with seasoning powder. The defatted sample to seasoning powder ratio was 100:3 (w/w), and approximately 50% of the seasoning powder adhered to the product. The vacuum-fried samples were cooled in an environment with a relative humidity of 34% at 25°C, and were then packed in aluminum foil laminated bags (PET/Al/PE) containing deoxidizer. Shiitake that has been immersed in 35°Brix MO syrup and 30, 35, and 40°Brix IMO syrup is designated as C, 30IMO, 35IMO, and 40IMO, respectively.

**Soluble solids**

The candied caps or stipes (20 g) and deionized water (80 g) were mixed in a mixing bottle and homogenized using a 10 speed blender (Sunbeam-Oster Co., Pittsburgh, PA, USA) at a speed STIR setting for 90 s. The homogeneous solution was poured into a centrifuge bottle and centrifuged at 3600 rpm for 10 min (2100 × g), and the soluble solids of the supernatant were measured using a hand refractometer (Atago Co., Tokyo, Japan). After uniformly mixing the syrup solution, syrup (25 g) and deionized water (100 g) were combined in a beaker, stirred well with a glass rod, and the soluble solids measured using a hand refractometer.

**Geometric dimension and weight**

The diameter, thickness, and length of the vacuum-fried shiitake cap and stipe crisps were measured with an absolute digimatic caliper (500–196-20, Mitutoyo, Kanagawa, Japan). A scale was used to determine the weight of the crisps. Each treatment has an average of 20 samples in terms of dimension and weight.

**Proximate composition, water activity, and sugar**

American Association of Cereal Chemists (AACC) approved methods 08–01.01, 30–25.01, 44–40.01, and 46–11.02 were used to determine the proximate compositional contents of vacuum-fried shiitake, including crude ash, crude fat, moisture, and crude protein. The nitrogen conversion factor for the sample, which is used to calculate the crude protein content was 4.38. The carbohydrate content (g/100 g) was calculated by subtracting the moisture, protein, fat, and ash content from 100 g of matter. The water activity (Aw) was measured using an AquaLab CX-2 water activity meter (Decagon Devices, Pullman, WA). The sugar content of IMO syrup, MO syrup and vacuum-fried shiitake were determined using the method of Lee et al. Each analysis was performed thrice.

**Color and breaking force**

The reflective color of shiitake crisps was determined using a color measurement spectrophotometer (ColorFlex-Diffuse, Hunter Associates Laboratory, Reston, VA, USA) with an aperture diameter of
10 mm. The colorimeter was set for CIE $L^*$, $a^*$ and $b^*$ values with a D65 illuminant at 10° and was calibrated using a standard white board ($X = 81.73$, $Y = 86.76$ and $Z = 92.56$). The hue angle ($h^*$, arctan $b^*/a^*$), chroma ($c^*$, $(a^2 + b^2)^{1/2}$), and total color difference ($\Delta E$) between the crisps and a control was calculated using the following equation:

$$\Delta E = [(L_c - L_{sc})^2 + (a_c - a_{sc})^2 + (b_c - b_{sc})^2]^{1/2},$$

Where $L^*$, $a^*$ and $b^*$ are the respective mean values for the control (c) and shiitake crisps (sc). The results from three different areas on each crisp were averaged and recorded as a single sample. The outcome for each treatment is an average of 10 samples. The breaking force for the vacuum-fried shiitake crisps was measured using a puncture test with a texture analyzer (TA-XT2, 25 kg model; Stable Micro Systems, Surrey, UK), with a slightly modified version of the method of Ren et al.[2] The shiitake crisps were placed over the end of a hollow cylinder and a stainless spherical probe (P/0.5S) was used to break the crisps. The texture analyzer was set to run at a test speed of 1 mm/s, a trigger force of 5 g, and a probe travel distance of 3 mm. Each treatment’s breaking force is an average of 10 samples.

**Consumer preference**

A nine-point hedonic scale (1 = dislike extremely, 5 = neither like nor dislike, 9 = like extremely) test was used to conduct a sensory evaluation for appearance, color, flavor, texture, oiliness, and overall opinion of the vacuum-fried shiitake crisps. Samples were placed on white plates and identified using random three-digit numbers. Each tester evaluated four samples for each sensory evaluation, and the samples were rated based on their opinion. The ingredients were not disclosed to the testers, and warm water was used to rinse the palate between samples to minimize any residual effect. The evaluation was conducted in a testing area with white light, a temperature of 25 ± 1°C, and relative humidity of 60 ± 5% RH. The untrained testers (80 in total, 38 males and 42 females, ages 19 to 30 years old) were Hungkuang University students.

**Statistical analysis**

Except for the dimension and weight ($n = 20$), color property and breaking force ($n = 10$) and hedonic test ($n = 80$), each measurement was repeated thrice. The experimental data was subjected to an analysis of variance using the Statistical Analysis System software package (SAS Institute, Cary, NC, USA). If a significant difference was found between treatments, Duncan’s multiple-range test was used to determine the differences between the mean values at the level of $\alpha = 0.05$.

**RESULTS AND DISCUSSION**

**Soluble solids**

The moisture content (g/100 g) of centrifuged caps and stipes is 83.8 and 76.4, respectively. Figure 1 depicts the change in soluble solids after centrifuged caps and stipes were immersed in various concentrations of boiled syrup for 1–6 h. There is no significant difference in the soluble solids for caps and syrup after soaking for 3–6 h, indicating that caps and syrup reach equilibrium after soaking for 3 h. The centrifuged caps were soaked in 35 °Brix MO syrup and in 30, 35 and 40 °Brix IMO syrups for 3 h. The respective soluble solids for candied caps are 20.5, 17.3, 20.3, and 22.7 °Brix. The soluble solids for the syrup samples are 21.4, 19.0, 21.6, and 24.1 °Brix, respectively.

There is no significant difference in the soluble solids for candied stipes and syrup after soaking for 3–6 h, so centrifuged stipes are balanced by soaking in various concentrations of boiled sugar solutions for 3 h (Figure 1). After immersing the centrifuged stipes in 35 °Brix MO syrup and 30, 35 and 40 °Brix IMO syrups for 3 h, the respective soluble solids of the candied stipes are 22.8, 19.6, 22.9 and 28.0 °Brix.
Brix. The soluble solids for the syrup samples are 26.0, 23.2, 26.0, and 31.4 °Brix, respectively. Therefore, if sugar is added to whole shiitake, the equilibrium time is also around 3 h. Candied stipes have higher soluble solids than candied caps, possibly due to the use of more impregnated syrup in the centrifuged stipes (stipes: syrup = 1:1.3, w/w) than in the centrifuged caps (caps: syrup = 1:1, w/w).

Physicochemical characteristics

For this study, caps and stipes were vacuum-fried after being soaked in various concentrations of syrup for 3 h. The resulting products are shown in Figure 2. All cap crisps have the same average diameter (28–29 mm), thickness (2.7–2.8 mm), and weight (1.5–1.6 g) (Table 1). The average diameter (7 mm), length (20 mm) and weight (0.5–0.6 g) of all stipe crisps are also not significantly different. The results show that there is no significant difference in the dimensions and weights of cap or stipe crisps prepared by soaking centrifuged caps and stipes in various concentrations of syrup and vacuum-frying.

Consumers are particular about the color of the product. Figure 2 shows that the surface color of the cap crisps differs noticeably. In terms of cap crisps, the \( L^* \) value (30) for the control is significantly lower than that for the 30IMO (36) and 35IMO (34) and \( a^* \) and \( b^* \) values for the control (9, 15) are significantly lower than those for 30IMO (10.8, 19) (Table 1). The \( L^* \) (36 to 31), \( a^* \) (10.8 to 10.0) and \( b^* \) (19 to 13) values for cap crisps made with IMO syrup decreased significantly with increasing sugar content in IMO syrup. The surface color of the cap crisps is darker, less red and less yellow. Although this study detected no reducing sugars in raw shiitake,\(^{19}\) IMO syrup contains reducing sugars such as glucose and maltose, while the caps contain amino acids, so samples may be darkened by the Maillard reaction. Oil intake also affects the final color of fried food.\(^{20}\) The \( L^*, a^*, \) and \( b^* \) values for stipe crisps soaked in IMO syrup do not differ significantly from those of the control.

The \( h^* \) value represents the true color: 0° is red, 60° is yellow, 120° is green, 180° is cyan, 240° is blue, and 300° is magenta, according to the classical layout.\(^{21}\) The \( h^* \) values for all cap and stipe crisps range from 53° to 60° and 71° to 73°, respectively (Table 1). The \( L^* \) values for stipe crisps are significantly higher than those for cap crisps. This shows that the yellow color of stipe crisps is brighter compared to cap crisps. The \( c^* \) represents the color intensity. The higher the value, the more
intense and vivid is the color. The $c^*$ values for all cap crisps range from 16–21, with 30IMO having the highest value. There is no significant difference between the control, 35IMO and 40IMO, and there is no significant difference in the $c^*$ values (19 to 20) for stipe crisps.

The difference between the color of two samples is $ΔE$ \cite{22,23}. If $0 < ΔE < 1$: a standard observer cannot recognize this color difference; if $1 < ΔE < 2$: only an experienced observer can judge this difference; if $2 < ΔE < 3.5$: an inexperienced observer can observe this difference; if $3.5 < ΔE < 5$: any observer can easily judge this difference; and if $ΔE > 5$: an observer can notice two different colors.

The respective $ΔE$ values for 30IMO, 35IMO, and 40IMO cap crisps and the control are 6.52, 3.75, and 2.18 (Table 1). The surface color of cap crisps made with IMO syrup differs significantly from that of the control. The color difference between the IMO impregnated sugar solution and the control

| Cap | 30IMO | 35IMO | 40IMO |
|-----|-------|-------|-------|
| Diameter (mm) | 29±4 | 29±4 | 28±4 | 7±1 (5–9) | 7±1 (4–11) | 7±1 (5–10) | 7±1 (5–8) |
| Thickness (mm) | 2.7±0.7 | 2.8±0.8 | 2.7±0.6 | 2.8±0.8 | 20±4 (13–28) | 20±3 (15–26) | 20±4 (12–28) | 20±3 (16–28) |
| Length (mm) | 1.5±0.3 | 1.5±0.4 | 1.6±0.3 | 1.6±0.4 | 6±0.1 (0.4–1.0) | 6±0.2 (0.4–1.0) | 5±0.2 (0.3–1.0) | 6±0.1 (0.3–0.9) |

Each value is expressed as mean ± standard deviation (n = 20 for dimension and weight, n = 10 for color property and breaking force). Values with different lowercase letters within a row differ significantly (p < 0.05). Numbers in parenthesis are the range of dimension or weight of samples. Shiitake soaked in 35°Brix MO syrup and 30, 35, and 40°Brix IMO syrup were designated as C, 30IMO, 35IMO and 40IMO, respectively.

Table 1. Dimension, weight, color property, and breaking force of vacuum-fried shiitake crisps.
group becomes smaller as the concentration of IMO impregnated sugar solution increases. The \( \Delta E \) values for cap crisps for 30IMO and 35IMO, 30IMO and 40IMO, and 35IMO and 40IMO are 2.77, 4.34, and 1.57, respectively, so all cap crisps are different in color and are distinguishable by the naked eye.

For stipe crisps, the respective \( \Delta E \) values for 30IMO, 35IMO and 40IMO and the control are 0.79, 1.96, and 1.28 (Table 1). The surface color of stipe crisps made with IMO syrup differs from the control and must be judged by an experienced observer. The respective \( \Delta E \) values for stipe crisps for 30IMO and 35IMO, 30IMO and 40IMO, and 35IMO and 40IMO are 1.17, 0.49, and 0.68. This shows that all stipe crisps made with IMO syrup are similar in color and difficult to distinguish.

Breaking force is an indicator of the crispness of vacuum-fried crisps. A lower breaking force corresponds to greater crispiness.\(^2\) The breaking force for caps crisp ranges from 41–42 N and there is no significant difference between treatments (Table 1). The breaking force for stipe crisps is lower and ranges from 34–35 N, indicating that there is no significant difference in breaking force between treatments. According to the data, stipe crisps are crisper than cap crisps.

### Proximate composition, water activity and sugars

The moisture (g/100 g) content for cap and stipe crisps ranges from 0.5–0.78 and 0.5–0.86 (Table 2). Water activity is an important quality characteristic of food, which is used to predict the stability and safety of food, in terms of microbial growth and rates of physicochemical deteriorative reactions.\(^2\) The Aw value for cap and stipe crisps ranges from 0.25–0.27 and 0.245–0.256, respectively (Table 2). Fontana\(^{24}\) noted that the limit value for Aw for any microbial growth is less than 0.6. For this study, the Aw value for all crisps is less than 0.27, so vacuum-frying maintains the quality and prolongs the shelf life of products. This result is similar to that of Ren et al.\(^2\)\(^{25}\)

The crude protein and crude fat content of cap and stipe crisps made with IMO syrup decreases as the IMO syrup concentration increases, but the carbohydrate content increases (Table 2). The crude ash and carbohydrate content of cap crisps is higher than that of stipe crisps, but the crude protein and crude fat contents are lower. The crude fat content of stipe crisps is about 2.2–2.7 times that of cap crisps, possibly because the cell wall structure of stipes is much tighter than that of caps, making oil more difficult to remove during centrifugation. The crude fat content of vacuum-fried crisps decreases as the concentration of soluble solids in the syrup increases because osmotic treatment significantly reduces the moisture content of a sample before frying, so vacuum-fried crisps have a lower final oil content.\(^2\)\(^{25}\) As a result, the more sugar there is in the cell during frying, the less likely it is that oil will enter.

This study shows that the IMO content of shiitake crisps increases significantly as levels of IMO syrup increase (Table 3). The sugar composition of the control included glucose, maltose, maltotriose and maltotetraose. Glucose, maltose, isomaltoose, maltotriose, panose, isomaltotriose, maltotetraose, and isomaltose are all sugars found in crisps made with IMO syrup. For cap crisps, the total amount (g/100 g dry matter) of sugars in the control, 30IMO, 35IMO, and 40IMO is 45, 36.3, 45, and 52.6, respectively. The total IMO content (g/100 g dry matter) of 30IMO, 35IMO and 40IMO is 21.6, 26.6, and 31.8, respectively.

In terms of stipe crisps, maltose and panose are the main sugar in the control and the IMO treatments, respectively. The total IMO content (g/100 g dry matter) of 30IMO, 35IMO, and 40IMO is 17.5, 20.51 and 24.4, respectively. The total sugar content (g/100 g dry matter) of stipe crisps decreases in the order: 40IMO > Control = 35IMO > 30IMO. Overall, total sugar content is lower in stipe crisps than in cap crisps.

Several studies\(^{9–14}\) show that a daily intake of 10 g IMO improves bowel movements, causes bifidobacteria to proliferate, and regulates blood lipids in humans. Therefore, the recommended daily intake for 30IMO, 35IMO and 40IMO cap crisps is 46.3, 37.6, and 31.4 g, respectively. The recommended daily intake for 30IMO, 35IMO and 40IMO stipe crisps is 57.1, 48.3 and 41.0 g, respectively. The energy value of IMO is \( \approx 75\% \) that of maltose.\(^{26}\) Tables 2 and 3 show that 40IMO vacuum-fried
Table 2. Proximate composition and water activity of vacuum-fried shiitake crisps.

|                | Cap            | Stipe          |
|----------------|----------------|----------------|
|                | C  | 30IMO | 35IMO | 40IMO | C  | 30IMO | 35IMO | 40IMO |
| Moisture       | 0.6 ± 0.2bc’d  | 0.78 ± 0.09ab  | 0.66 ± 0.06abcd | 0.5 ± 0.3cd  | 0.5 ± 0.1d  | 0.74 ± 0.09abc | 0.7 ± 0.1abc | 0.86 ± 0.08a  |
| Crude protein  | 8.2 ± 0.3bc’d  | 8.9 ± 0.3bc’d  | 8.6 ± 0.4ab’d  | 7.21 ± 0.01’d | 8.8 ± 0.3bd  | 9.2 ± 0.6ab’d | 8.8 ± 0.2ab’d | 7.87 ± 0.01c’ |
| Crude fat      | 11.6 ± 0.6d’  | 12.03 ± 0.09d’ | 10.3 ± 0.1e’  | 6.99 ± 0.07f’ | 25 ± 1b’d’ | 26.8 ± 0.6e’ | 25.3 ± 0.2b’d’ | 18.57 ± 0.04c’ |
| Crude ash      | 1.27 ± 0.06a’ | 1.1 ± 0.1b’   | 1.09 ± 0.07d’ | 1.11 ± 0.07b’d | 0.58 ± 0.01c’ | 0.71 ± 0.02c’ | 0.59 ± 0.02c’ | 0.65 ± 0.07c’  |
| Carbohydrate   | 78.9 ± 0.1c’  | 78.1 ± 0.6d’  | 80.0 ± 0.3b’  | 84.7 ± 0.1a’  | 65.7 ± 0.8f’ | 63.28 ± 0.05g’ | 65.33 ± 0.03f’ | 72.91 ± 0.07e’ |
| Water activity | 0.26 ± 0.03abc | 0.268 ± 0.003a | 0.27 ± 0.01ab | 0.25 ± 0.01abc | 0.245 ± 0.006c’ | 0.254 ± 0.006abc | 0.256 ± 0.009abc | 0.252 ± 0.003bc’ |

Each value is expressed as mean ± standard deviation (n = 3). Values with different lowercase letters within a row differ significantly (p < 0.05). Shiitake soaked in 35°Brix MO syrup and 30, 35, and 40°Brix IMO syrup were designated as C, 30IMO, 35IMO and 40IMO, respectively. Moisture was presented on air-dried matter basis, others were presented on dry matter basis.
Table 3. Sugar content of vacuum-fried shiitake crisps.

|                  | Cap                                      | Stipe                                   |
|------------------|------------------------------------------|------------------------------------------|
|                  | C            | 30IMO        | 35IMO        | 40IMO        | C            | 30IMO        | 35IMO        | 40IMO        |
| Glucose          | 1.22 ± 0.08<sup>f</sup>                  | 6.8 ± 0.3<sup>d</sup>                   | 8.6 ± 0.2<sup>b</sup>                   | 9.9 ± 0.2<sup>a</sup> | 1.28 ± 0.05<sup>f</sup> | 5.47 ± 0.06<sup>e</sup> | 6.53 ± 0.09<sup>d</sup> | 7.3 ± 0.2<sup>c</sup> |
| Maltose          | 20.8 ± 0.6<sup>d</sup>                   | 5.4 ± 0.2<sup>f</sup>                   | 6.72 ± 0.09<sup>d</sup>                 | 7.4 ± 0.2<sup>c</sup> | 18.7 ± 0.3<sup>b</sup> | 4.3 ± 0.1<sup>g</sup> | 5.1 ± 0.2<sup>f</sup> | 6.1 ± 0.2<sup>e</sup> |
| Isomaltose       | nd<sup>d</sup>                            | 5.5 ± 0.1<sup>d</sup>                   | 6.8 ± 0.1<sup>b</sup>                   | 7.6 ± 0.2<sup>d</sup> | nd<sup>d</sup> | 4.6 ± 0.1<sup>f</sup> | 5.3 ± 0.2<sup>c</sup> | 6.34 ± 0.09<sup>e</sup> |
| Maltotriose      | 10.28 ± 0.41<sup>a</sup>                 | 1.3 ± 0.2<sup>de</sup>                  | 1.5 ± 0.2<sup>cd</sup>                  | 1.82 ± 0.09<sup>c</sup> | 7.4 ± 0.1<sup>b</sup> | 0.87 ± 0.03<sup>f</sup> | 1.2 ± 0.1<sup>ef</sup> | 1.32 ± 0.08<sup>de</sup> |
| Panose           | nd<sup>d</sup>                            | 11.0 ± 0.3<sup>d</sup>                  | 13.5 ± 0.2<sup>b</sup>                  | 16.5 ± 0.7<sup>a</sup> | nd<sup>d</sup> | 8.9 ± 0.1<sup>e</sup> | 10.5 ± 0.6<sup>d</sup> | 12.5 ± 0.2<sup>c</sup> |
| Isomaltotriose   | nd<sup>d</sup>                            | 3.66 ± 0.09<sup>cd</sup>                | 4.4 ± 0.1<sup>h</sup>                   | 5.2 ± 0.2<sup>c</sup> | nd<sup>d</sup> | 2.9 ± 0.1<sup>g</sup> | 3.4 ± 0.1<sup>d</sup> | 3.74 ± 0.08<sup>e</sup> |
| Maltotetraose    | 13.07 ± 0.39<sup>g</sup>                 | 1.2 ± 0.1<sup>ef</sup>                  | 1.58 ± 0.07<sup>c</sup>                 | 1.70 ± 0.01<sup>c</sup> | 9.6 ± 0.2<sup>b</sup> | 0.93 ± 0.02<sup>f</sup> | 1.2 ± 0.1<sup>cd</sup> | 1.5 ± 0.1<sup>cd</sup> |
| Isomaltotetraose | nd<sup>d</sup>                            | 1.4 ± 0.2<sup>c</sup>                   | 1.88 ± 0.06<sup>b</sup>                 | 2.5 ± 0.1<sup>h</sup> | nd<sup>d</sup> | 1.1 ± 0.1<sup>d</sup> | 1.49 ± 0.02<sup>c</sup> | 1.8 ± 0.1<sup>b</sup> |
| Total IMO<sup>1</sup> | nd<sup>d</sup>                          | 21.6 ± 0.3<sup>d</sup>                  | 26.6 ± 0.3<sup>b</sup>                  | 31.8 ± 0.6<sup>a</sup> | nd<sup>d</sup> | 17.5 ± 0.2<sup>ef</sup> | 20.7 ± 0.4<sup>g</sup> | 24.4 ± 0.4<sup>c</sup> |
| Total            | 45 ± 1<sup>b</sup>                       | 36.3 ± 0.3<sup>d</sup>                  | 45.0 ± 0.2<sup>b</sup>                  | 52.6 ± 0.2<sup>a</sup> | 37.0 ± 0.2<sup>d</sup> | 29.1 ± 0.3<sup>f</sup> | 34.7 ± 0.4<sup>e</sup> | 40.6 ± 0.3<sup>c</sup> |

Each value is expressed as mean ± standard deviation (n = 3). Values with different lowercase letters within a row differ significantly (p < 0.05). Shiitake soaked in 35°Brix IMO syrup and 30, 35, and 40° Brix IMO syrup were designated as C, 30IMO, 35IMO and 40IMO, respectively. Total IMO = Isomaltose + Panose + Isomaltotriose + Isomaltotetraose. nd = Not detected.
shiitake crisps have the lowest fat content and the highest IMO content, so 40IMO products have the greatest positive effect on health.

**Consumer preference**

Eighty testers were used for a nine-point hedonic scale test. There is no significant difference in the appearance (6.9–7.1), color (7.0–7.2), flavor (7.0–7.2), texture (7.1–7.2), oiliness (7.2–7.4), and overall opinion (7.0–7.1) of all cap crisps with no added seasoning powder (6 = like slightly, 7 = like and 8 = like very much) (**Figure 3**). When seasoning powder is sprinkled on cap crisps, the flavor (8.1–8.2) and overall liking (8.1–8.2) scores both rise to “like very much.” Other hedonic sensory characteristics of cap crisps are not affected by the addition of seasoning powder. The color (**Table 1** and **Figure 2**) and crude fat content (**Table 2**) of cap crisps prepared with different syrup concentrations differ, but this has no effect on the tester’s score for product color and oiliness.

The appearance, color, flavor, texture, oiliness and overall liking scores for stipe crisps without seasoning powder range from 6.1–6.5. When stipe crisps are sprinkled with seasoning powder, the average flavor and overall liking scores range from 7.2–7.4. The sensory evaluation results show that cap crisps are more preferred than stipe crisps. The addition of seasoning powder to vacuum-fried shiitake crisps improves the flavor and overall liking scores, possibly because of the large loss of flavor components due to blanching and centrifugation in the manufacturing process.\(^1_{,19}\)

**CONCLUSION**

Shiitake crisps that have been vacuum-fried are popular all over the world. Many studies have shown that IMO has numerous health benefits. The results of this study’s physicochemical and sensory quality characteristics show that functional IMO syrup in a vacuum-fried shiitake formula is a viable alternative to traditional MO syrup. The health benefits of vacuum-fried shiitake crisps made with IMO syrup outweigh those of crisps made with MO syrup. Vacuum-fried shiitake crisps containing IMO are developed to be novel and functional. When the MO syrup in vacuum-fried shiitake crisps is
replaced with IMO syrup, the result is lower-calorie crisps with healthy properties. The sensory quality characteristics of vacuum-fried shiitake stipe crisps made with IMO or MO syrup are also lower than those of cap crisps, but when seasoning powder is added, the score for overall liking is "like" (7 points). This result shows that stipes can also be used to make vacuum-fried crisps and increase profitability for manufacturers.

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