Enrichment of rice-based extrudates with Cactus *Opuntia dillenii* seed powder: a novel source of fiber and antioxidants

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Revised: 21 October 2017 / Accepted: 26 October 2017 / Published online: 7 November 2017
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Abstract The present study investigated the effects of adding the powder of cactus *Opuntia dillenii* (*O. dillenii*) seeds on the functional properties, fiber, antioxidants and acceptability of rice-based extrudates. The control blend consisting basically of rice flour was replaced with *O. dillenii* seed powder at 2, 4, 6, 8, 10, 15 and 20% then extruded at the optimum processing conditions. The extruded products were evaluated for their chemical composition, functional properties, color attributes, antioxidant activity and sensory characteristics. The results revealed that adding *O. dillenii* seeds powder enhanced the fiber, phenolics, flavonoid contents and antioxidant activity of extrudates. Expansion, bulk density and breaking strength were significantly decreased, while water absorption index, water solubility index and oil absorption index were significantly increased compared to the control. Furthermore, the mean scores of sensory evaluation indicated clear improvements in all tested sensory attributes, which significantly increased by increasing the level of *O. dillenii* seed powder up to 15%. The results confirmed that *O. dillenii* seed powder could be incorporated in rice to develop snack products of acceptable functional, nutritional and sensory properties.

Keywords *Opuntia dillenii* seeds powder · Functional properties · Sensory properties · Fiber · Antioxidants

Introduction

Nowadays, there is a growing interest in utilizing the residues generated by the food industry as food supplements. As the consumers prefer natural supplements and avoid synthetic ingredients, fiber-rich by-products, rich in bioactive compounds, are important raw materials for food processors. Increased intake of dietary fiber could be associated with numerous health benefits, including reduced risk of coronary heart disease, diabetes, obesity, and some forms of cancer (Mann and Cummings 2009). Supplementation with dietary fiber may result in health promoting foods, low in calories, cholesterol and fat and would modify textural properties. As the most important genus of Cactaceae family with regard to food products, *Opuntia* includes a huge number of species and varieties. For instance, *Opuntia dillenii* (*O. dillenii*) is one of the species that received a great attention from researchers for using it as food products because it exhibited antioxidants and functional properties (Moussa-Ayoub et al. 2011, 2015). The seeds of *Opuntia* (xoconostle cultivars) are considered as potential food by-products with a high content of unsaturated fatty acids, especially polyunsaturated fatty acids (PUFAs), which are associated with a reduced risk of developing cardiovascular, inflammatory and autoimmune diseases (Simopoulos 2002). Similar to xoconostles, *O. dillenii* fruits at full ripe stage contain about 39.66% of small and hard seeds (Hamed 2015).

Most of the previous studies with regard to the fortification with cactus *Opuntia* were carried out on the whole fruits. In this regard, El-Samahy et al. (2007) evaluated physical, textural and sensory properties of rice-based extruded products fortified with concentrated cactus fruit pulps from *O. ficus-indica*. Furthermore, Sarkar et al. (2011) investigated the impact of adding *O. ficus-indica*

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puree on the physical and textural properties of rice-based extrusion products. Recently, Moussa-Ayoub et al. (2015) investigated the flavonol profile of cactus fruits (*O. ficus-indica*) enriched cereal-based extrudates. Extrusion has been used to develop various types of snack foods, mainly from corn meal, rice, wheat flour or potato flour, in many shapes and variety of textures. Incorporation of by-products from the food industry using extrusion technology in order to improve the nutritional characteristics of ready-to-eat snacks is well documented (Stojceska et al. 2009). Extrusion cooking technology is a versatile and efficient method of converting raw materials into finished food products. It can replace many conventional processes in food and feed industry, because it is unique among heat processes in that the material is subjected to intense mechanical shear; moistened starchy or proteinaceous foods are worked into viscous, plastic-like dough and cooked before being forced through the die.

Thus, the objective of the present study was therefore to investigate the effect of adding the powder of seeds of cactus *O. dillenii* on functional properties, fiber content, antioxidant activity and acceptability of the resultant rice-based extrudates. To the best of our knowledge, this is the first study in utilizing the seed of *O. dillenii* in food manufacturing.

Materials and methods

Raw materials

Full ripe cactus fruits (*O. dillenii*) were harvested from the orchard of Faculty of Agriculture, Suez Canal University, Ismailia Governorate, Egypt during December 2014. Fruits were washed and the glochides and the two distal parts (top and bottom parts) were entirely removed. The fruits were then mashed in a mixer for 15 s and the seeds were manually separated, washed and dried by hot air in a convective dryer (WT-binder, Type F115, Germany) at 50 °C, air velocity of 0.6 m/s at the ambient relative humidity for 6 h. The seeds were ground to homogenous particle size (300–500 µm) using a laboratory mill (Brabender Automat Mill Quandrumat Senior, Germany). Rice was purchased from a local market, then ground to particle size of 300–500 µm using a laboratory mill (Brabender Automat Mill Quandrumat Senior, Germany). The chemical composition of raw materials is shown in Table 1.

Chemicals and reagents

Trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid), quercetin, DPPH (2,2-diphenyl-1-picrylhydrazyl) and ABTS (2,2'-azino-bis (3-ethylbenzothiazoline–

Table 1 Chemical composition, total phenolics, total flavonoid contents and antioxidant activity of cactus *Opuntia dillenii* seeds powder and rice flour (on dry weight basis)

Raw materials	Moisture content (%)	Protein (%)	Ether extract (%)	Crude fiber (%)	Ash (%)	Available carbohydrates ^a (%)	Total phenolics (mg 100 g ⁻¹)	Total flavonoids (mg 100 g ⁻¹)	DPPH (%)	ABTS (µmol trolox 100 g ⁻¹)
Cactus <i>Opuntia dillenii</i> seeds powder	5.23 ± 0.25	4.84 ± 0.06	7.89 ± 0.02	52.78 ± 0.64	3.56 ± 0.33	30.94 ± 0.77	39.56 ± 2.64	595.00 ± 8.24	7.47 ± 0.06	108.20 ± 5.76
Rice flour	12.77 ± 0.42	10.28 ± 0.04	1.15 ± 0.09	0.24 ± 0.02	1.04 ± 0.05	87.29 ± 0.13	31.66 ± 3.34	309.52 ± 21.47	2.56 ± 0.49	48.95 ± 4.84

Each value is mean ± standard deviation of triplicates

^a The available carbohydrates were calculated by difference

6-sulfonic acid) were all obtained from Sigma-Aldrich Co., St. Louis, MO, USA. Folin-Ciocalteu's phenol reagent and gallic acid were purchased from Fluka Company. All other chemicals were of analytical grade.

Methods

Preparation of formulations

The seeds powder of *Opuntia dillenii* was blended to the rice grits in ratios of 0 (control), 2, 4, 6, 8, 10, 15 and 20%. The moisture in all mixtures was adjusted to 16%. The samples were packed in polyethylene bags and kept in the refrigerator at (4 °C) overnight (~ 12 h) to equilibrate the moisture.

Extrusion cooking conditions

Extrusion cooking process for the prepared formulas was undertaken using a Barabender laboratory single-screw extruder (20 DN, Model No. 186501, type 832500) equipped with feeding device (AEV300, NO.141923, type GNF1014/2) and a 3 mm round die. The screw speed in cooking and feeding zones was set at 250 and 160 rpm (about 7.2 kg/h), respectively with screw compression ratio of 4:1. The temperatures of feeding, cooking and die zones were adjusted at 100, 180 and 180 °C, respectively. The resulted extrudates were directly dried in a forced-air oven drier at 100 °C for 5 min and allowed to reach room temperature (Morsy et al. 2015). One part of the resulted extrudate samples was used directly for sensory evaluation, and the other part was ground (particle size < 500 µm) and stored at 4 °C in polyethylene sealed bags until analysis.

Chemical composition

The moisture, crude protein ($N \times 6.25$), ether extract, crude fiber and ash contents were determined according to AOAC (2000) methods. Carbohydrates were calculated by difference.

Functional properties

The expansion ratio (ER) was determined according to Chinnaswamy and Hanna (1988), bulk density (BD) was determined by the method of Alvarez-Martinez et al. (1988), breaking strength (BS) was determined using Barabender Struct-O-Graph (Model No. 8603, OHG, Dusburg). Water absorption index (WAI) and water solubility index (WSI) were determined according to the method of Anderson et al. (1970). Oil absorption index (OAI) was determined according to the method of Liadakis et al. (1993).

Color measurement

The CIELab coordinates (L^* , a^* , and b^*) were directly read with a spectrophotocolorimeter (Konica Minolta Sensing, Inc. Osaka, Japan). In this coordinate system, the L^* value is a measure of lightness, ranging from 0 (black) to 100 (white), the a^* value ranges from − 100 (greenness) to +100 (redness), and the b^* value ranges from − 100 (blueness) to + 100 (yellowness). The whiteness index (WI) was calculated according to Bolin and Huxsoll (1991).

Total phenolics, total flavonoids and antioxidants activity

Total phenolics and flavonoid contents were determined according to the method of Barros et al. (2011). DPPH radical-scavenging activity and the trolox equivalent antioxidant capacity (TEAC) assay (measure the ability of the samples extract to scavenge the ABTS radical) were determined as described by Morsy et al. (2015).

Sensory evaluation

The sensory attributes including; taste, crispness, odor, chewiness, color, surface characteristics, pore distribution and overall acceptability were judged by staff members and trained personnel of Food Technology Department, Fac. of Agric., Suez Canal University, Ismailia, Egypt. All the above mentioned attributes were evaluated using a hedonic scale from 1 to 10. Scale 1 was for dislike extremely and 10 for like extremely. The overall acceptability of the samples was calculated from the total score of the judged attributes. The Duo-Trio sensory test was applied under controlled conditions (Meilgaard et al. 2006).

Statistical analysis

All data were expressed as mean $\pm$ standard deviation (SD). The analysis of variance (ANOVA) was performed using SPSS program (version 17.0 SPSS Inc) and Duncan's multiple comparison test were used to detect significant differences between blends. Significant differences were defined at $p \leq 0.05$.

Results and discussion

Chemical composition of cactus *O. dillenii* seeds powder and rice flour

The results presented in Table 1 show that *Opuntia dillenii* seeds powder had 4.84% protein, 7.89% ether extract,

3.56% ash, 30.94% available carbohydrates and high fiber content 52.78%. The contents of protein, ether extract and fiber of *O. dillenii* seeds were lower than those reported by Morales et al. (2012) for the seeds of *O. joconostle* and *O. matdae*. The differences in chemical composition may be attributed to the variations in the method of analysis, variety and maturation of the seeds. Morales et al. (2012) reported that the possibility and potential use of *Opuntia* seeds for nutritional proposes and other food products as they are a source of fiber, phenolics, flavonoids, PUFAs and tocopherols (specially γ -tocopherol), which provide a good antioxidant capacity. Badami and Thakkar (1984) concluded that the air dried *O. dillenii* seeds contained about 7.5% oil and the linoleic acid was the predominate fatty acid. As shown in Table 1, the seeds of *O. dillenii* are a good source of total phenolics, flavonoids and antioxidant activity (39.56, 595.00 mg 100 g⁻¹ and 7.47% or 108.2 μ mol trolox 100 g⁻¹, respectively). The obtained results are in agreement with those reported for other cactus varieties (Hamed 2015; Moussa-Ayoub et al. 2011, 2015).

Chemical composition

As shown in Table 2, the chemical composition of rice-based extrudates fortified with *O. dillenii* seed powder was significantly ($p \leq 0.05$) affected by material ratio (*O. dillenii* seeds/rice). The results showed that the incorporation of *O. dillenii* seed powder in the extrudate formulas significantly decreased carbohydrates content in the resulting extrudates. A slight decrease in the protein content at the higher concentrations of *O. dillenii* seed powder were observed. On the other hand, the incorporation of seed powder enhanced the ether extract, fiber and ash contents. As the incorporation of *O. dillenii* seed powder increased, the crude fiber content of the resulted extrudates

significantly increased from 0.22 for control formula to 8.04 g 100 g⁻¹ on dry weight basis for formula containing 15% seed powder. A similar trend was reported previously for Jew's mallow leaves-rice based extrudates (Morsy et al. 2015).

Functional properties

Expansion ratio (ER)

The amount of expansion in food depends basically on the difference between the vapor pressure of water and the atmospheric pressure, as well as the ability of the exiting product to sustain expansion. As expected, increasing the level of *O. dillenii* seed powder resulted in a significant decrease ($p \leq 0.05$) in expansion of the extrudates compared with the control sample (Table 3). Similar results were observed by Anton et al. (2009) for common bean, Potter et al. (2013) for fruit powders and Morsy et al. (2015) for dried Jew's mallow leaves extrudates. The decline in expansion can be explained on the basis that fiber can rupture cell walls and prevent air bubbles from expanding to their maximum potential (Pérez-Navarrete et al. 2006). Furthermore, *O. dillenii* seed powder has a considerably amount of dietary fiber (52.78%), fat (7.89%) and did not provide enough viscous behavior inside the barrel which reduced the expansion. These results are in agreement with those reported by Duarte et al. (2009), where addition of soy bean hull on the extrusion of corn grits reduced the expansion of the extrudates. Usually, the addition of low molecular weight material in a mixture with starch causes a reduction in the overall expansion. The increases in fat content by incorporation of *O. dillenii* seed powder resulted in decreases in expansion of the resulted extrudates. Feng and Lee (2014) reported that presence of higher fat content

Table 2 Chemical composition (g 100 g⁻¹ dry weight) of the *O. dillenii* seeds powder-rice based extrudates

Extrudate type	Moisture content	Protein	Ether extract	Crude fiber	Ash	Available carbohydrates ^a
Rice flour (control)	9.20 ^{bc} ± 0.17	10.67 ^a ± 0.31	1.57 ^g ± 0.16	0.22 ^h ± 0.02	1.00 ^f ± 0.04	86.55 ^a ± 0.13
Cactus <i>O. dillenii</i> seeds powder						
2%	9.77 ^a ± 0.12	10.62 ^a ± 0.19	1.88 ^f ± 0.03	1.30 ^g ± 0.03	1.34 ^e ± 0.16	84.87 ^b ± 0.20
4%	9.30 ^b ± 0.10	10.58 ^a ± 0.20	2.03 ^e ± 0.07	2.36 ^f ± 0.06	1.83 ^d ± 0.11	83.21 ^c ± 0.21
6%	9.00 ^{bcd} ± 0.17	10.21 ^b ± 0.06	2.15 ^{de} ± 0.03	3.41 ^e ± 0.03	1.96 ^{cd} ± 0.06	82.27 ^d ± 0.11
8%	8.93 ^{cd} ± 0.25	10.03 ^{bc} ± 0.28	2.28 ^{cd} ± 0.10	4.52 ^d ± 0.07	2.07 ^{bc} ± 0.06	81.11 ^e ± 0.26
10%	9.23 ^{bc} ± 0.15	9.83 ^{cd} ± 0.06	2.37 ^{bc} ± 0.09	5.33 ^c ± 0.15	2.09 ^{bc} ± 0.05	80.38 ^f ± 0.16
15%	8.73 ^d ± 0.21	9.52 ^d ± 0.07	2.44 ^b ± 0.04	8.04 ^b ± 0.08	2.17 ^b ± 0.06	77.82 ^g ± 0.14
20%	8.73 ^d ± 0.12	9.12 ^e ± 0.02	2.63 ^a ± 0.03	10.61 ^a ± 0.07	2.33 ^a ± 0.08	75.32 ^h ± 0.21

Each value is mean ± standard deviation of triplicates

Means within the same column having the same superscript letter are not significantly different ($p \leq 0.05$)

^a The available carbohydrates were calculated by difference

Table 3 Functional properties of the *O. dillenii* seeds powder-rice based extrudates

Extrudate type	ER	BD (g ml ⁻¹)	BS (BU)	WAI (g g ⁻¹)	WSI (%)	OAI (ml g ⁻¹)
Rice flour (control)	3.27 ^a ± 0.29	0.52 ^a ± 0.02	832.80 ^a ± 88.82	9.01 ^c ± 0.50	23.00 ^{bc} ± 2.00	2.70 ^b ± 0.20
Cactus <i>O. dillenii</i> seeds powder						
2%	3.08 ^b ± 0.15	0.49 ^a ± 0.04	684.00 ^b ± 61.68	7.20 ^c ± 0.30	28.00 ^a ± 0.50	2.10 ^d ± 0.10
4%	3.07 ^b ± 0.11	0.44 ^b ± 0.01	582.00 ^c ± 44.92	7.49 ^c ± 0.20	26.00 ^{ab} ± 6.24	2.23 ^{cd} ± 0.06
6%	3.06 ^b ± 0.16	0.43 ^b ± 0.02	526.00 ^d ± 46.95	8.31 ^d ± 0.60	18.17 ^d ± 1.76	2.47 ^{bc} ± 0.12
8%	3.05 ^b ± 0.10	0.41 ^{bc} ± 0.01	482.00 ^{de} ± 61.61	9.12 ^c ± 0.12	25.53 ^{ab} ± 2.25	2.37 ^c ± 0.12
10%	2.94 ^{bc} ± 0.10	0.42 ^{bc} ± 0.02	478.00 ^{de} ± 65.46	11.27 ^b ± 0.01	18.83 ^{cd} ± 0.29	2.47 ^{bc} ± 0.12
15%	2.81 ^c ± 0.08	0.38 ^{cd} ± 0.03	432.00 ^{ef} ± 34.90	11.63 ^b ± 0.28	26.17 ^{ab} ± 0.29	3.27 ^a ± 0.21
20%	2.56 ^d ± 0.11	0.34 ^d ± 0.02	417.00 ^f ± 69.25	12.81 ^a ± 0.10	23.07 ^{bc} ± 0.40	3.27 ^a ± 0.15

Means within the same column having the same superscript letter are not significantly different ($p \leq 0.05$)

resulted in the lubrication of extruder barrel that may reduce barrel temperature during extrusion which cause a decrease in friction and degree of starch gelatinization then eventually decrease in expansion will occur. Additionally, more fat may cause a decrease in starch solubilization by lowering the mechanical breakdown of starch granules causing decrease in expansion. Seth et al. (2015) found that increase in feed moisture during extrusion results in more compact and dense extrudates, while an increase in the extrusion temperature generally results in a less compact and dense extrudate. Ghumman et al. (2016) found that lentil extrudates extruded at high feed moisture revealed decrease in expansion ratio with increase in extrusion temperature.

Bulk density (BD)

The bulk density is considered as an index of the extent of puffing. In all formulations with seed powder, the bulk density of the samples was significantly ($p \leq 0.05$) lower than the control sample except the sample at level of 2% *O. dillenii* seed powder (Table 3). However, there were small significant differences between the different *O. dillenii* seed samples themselves. Bulk density is related to expansion, with increasing expansion a decrease in the product density is expected. The results obtained in this study does not agree with these observations. Our findings may be attributed to the presence of soluble carbohydrates that absorb moisture and affect the expansion capability of the extrudates (Dehghan-Shoar et al. 2010). Furthermore, Gui et al. (2012) reported that the increase in barrel temperature resulted in decreased expansion and bulk density of extrudates only at a higher feed moisture content. Generally, heating during extrusion processing can significantly modify the texture of food materials, disrupting the structure and composition of the dietary fiber (Stojceska et al. 2009).

Breaking strength (BS)

As seen in Table 3, the breaking strength of the samples was significantly ($p \leq 0.05$) lower than the control. Samples blended with a small level of *O. dillenii* seed powder presented a high breaking strength whereas samples with higher levels of *O. dillenii* seed powder exhibited a low breaking strength, due to the smaller expansion when incorporating high levels of fiber which increase the crispness and decrease the breaking strength. These results are similar to those reported by Hashimoto and Grossmann (2003) for cassava bran/cassava starch and Holguin-Acuna et al. (2008) for maize bran/oat flour extrudates.

Water absorption index (WAI) and water solubility index (WSI)

WAI is important in the development of ready to eat foods, and a high absorption capacity may assure product cohesiveness. For different extruded samples, increasing the concentration of the *O. dillenii* seed powder content in the samples resulted in higher WAI values (Table 3). This can be explained by the high water absorption capacity of *O. dillenii* seed powder which is rich in fiber. These results are similar to those reported by Hashimoto and Grossmann (2003). Dietary fiber may interact with water by the polar and hydrophobic interactions, hydrogen bonding, and enclosure. These interactions resulted in variation in the flexibility of the fiber surface. WSI can be used as an indication of the degradation of molecular compounds and determine the degree of starch conversion in the extrusion process (Kaur et al. 2015). The values of WSI showed a slight increase, which can be the result of starch damage during extrusion due to high temperature (Stojceska et al. 2009). WSI is in relationship with the amount of soluble molecules, which is related to dextrinization. Extrusion at higher temperature resulted in increase the severity of heat

treatment in the extruder, this will increase the dextrinization which consequently increased WSI (Kaur et al. 2015).

Oil absorption index (OAI)

The water and oil absorption capacity of food protein depend on some important factors such as amino acid composition, protein conformation and surface polarity or hydrophobicity. The incorporation of *O. dillenii* seed powder significantly ($p \leq 0.05$) influenced the OAI (Table 3). The increase of *O. dillenii* seed powder decreased protein content and increased the crude fiber contents of the resulting extrudates (Table 2).

An increase in OAI was observed at the high concentration of *O. dillenii* seed powder (15 and 20%). Kinsella (1976) explained the mechanism of oil absorption as a physical entrapment of oil, whereas oil absorption capacity is related to the non-polar side chains of proteins. Results in Table 3 support the oil entrapment mechanism since the OAI values lower in those samples containing more protein. Oil absorption of extrudates relates to the presence of hydrophilic groups of starches present in flour (Kaur et al. 2015). The increase in oil absorption with incorporation of *O. dillenii* seed powder may be attributed to the increase in the porosity of the extrudates. Different protein concentrations, amounts of nonpolar amino acids, different conformational features and starch-protein-lipid binding could be reasons for different oil retaining characteristics.

Color attributes of extrudates

Color is an important quality parameter directly related to consumer acceptance and it is usually used to quantify the effect of extrusion cooking. Color attributes of the rice-based extrudates fortified with *O. dillenii* seed powder are shown in Table 4. The brightness (L^*) or color lightness varied significantly ($p \leq 0.05$) from 72.14 to 81.72 in a

scale of 0–100 for the rice-based extrudates fortified with different levels of *O. dillenii* seed powder. The control sample was brighter than those observed for the other formulations containing 2–20% *O. dillenii* seed powder. The a^* and b^* values varied from 0.44 and 10.88 for the control sample to 4.56 and 13.86 for snacks enriched with 20% of *O. dillenii* seeds. The values of a^* and b^* followed a reverse trend than those observed for the brightness. It is known that reducing sugars and proteins (amino acids) in foods can react under high processing temperatures to promote non-enzymatic browning (Maillard reaction), which results in darkening of the final products (Nayak et al. 2011). Therefore, the observed decrease in brightness and whiteness index (WI) may be attributed to the Maillard reaction, as a consequence of extrusion processing or to the incorporation of *O. dillenii* seeds powder that contains high fiber content. The decrease in L^* and increase in a^* and b^* values of the extrudates may be due to Maillard reaction which occur at high temperatures (Thakur et al. 2017). The results indicated that degradation of starch during extrusion processing increases the WSI which increased the a^* and b^* value. These results are in agreement with Kaur et al. (2015).

Total phenolics, total flavonoid contents and antioxidant activity

Incorporation the powder of *O. dillenii* seeds in the rice-based extrudates greatly enhanced the levels of total phenolics, total flavonoid contents and antioxidant activity in the resulted extrudates. The content of these compounds significantly increased with increasing the level of *O. dillenii* seed powder in the formula (Table 5). Brennan et al. (2011) reported that the higher total phenolic compound content in the extrudates may be due to its release from the cell wall matrix as a result of thermal processing. Moussa-Ayoub et al. (2015) reported that flavonol profiles of extruded products even at a low ratio of fortification were

Table 4 Color attributes (L^* , a^* , b^* and WI) of the *O. dillenii* seeds powder-rice based extrudates

Extrudate type	L^*	a^*	b^*	WI
Rice flour (control)	84.82 ^a ± 1.16	0.44 ^g ± 0.20	10.88 ^e ± 0.72	81.22 ^a ± 1.10
Cactus <i>O. dillenii</i> seeds powder				
2%	81.72 ^b ± 0.34	1.30 ^f ± 0.22	12.06 ^d ± 0.67	78.14 ^b ± 0.58
4%	80.44 ^c ± 0.30	2.06 ^e ± 0.35	12.22 ^{cd} ± 0.37	76.84 ^c ± 0.44
6%	79.72 ^{cd} ± 1.01	2.56 ^{de} ± 0.69	12.78 ^{bcd} ± 0.61	75.87 ^{cd} ± 0.85
8%	78.64 ^d ± 1.37	2.90 ^{cd} ± 0.51	12.68 ^{cd} ± 0.17	74.98 ^d ± 1.14
10%	76.46 ^e ± 1.44	3.40 ^c ± 0.46	12.96 ^{bc} ± 0.73	72.91 ^e ± 1.62
15%	74.24 ^f ± 2.01	4.00 ^b ± 0.30	13.54 ^{ab} ± 0.46	70.61 ^f ± 1.87
20%	72.14 ^g ± 1.26	4.56 ^a ± 1.14	13.86 ^a ± 1.98	68.51 ^g ± 1.97

Each value is mean ± standard deviation of ten replicates

Means within the same column having the same superscript letter are not significantly different ($p \leq 0.05$)

Table 5 Total phenolics, total flavonoid contents (mg 100 g⁻¹ dry weight) and antioxidant activity of the *O. dillenii* seeds powder-rice based extrudates

Extrudate type	Total phenolics	Total flavonoids	DPPH (%)	ABTS (μmol trolox 100 g ⁻¹)
Rice flour (control)	9.06 ^h ± 0.83	72.35 ^f ± 1.02	3.62 ^c ± 0.63	54.75 ^d ± 1.56
Cactus <i>O. dillenii</i> seeds powder				
2%	11.95 ^g ± 0.28	90.12 ^e ± 1.74	3.95 ^c ± 0.08	66.84 ^d ± 10.96
4%	13.66 ^f ± 0.42	101.09 ^{de} ± 12.10	4.37 ^c ± 0.42	58.60 ^d ± 17.54
6%	15.97 ^e ± 0.55	107.49 ^{de} ± 14.10	5.74 ^b ± 0.51	68.24 ^d ± 11.11
8%	18.24 ^d ± 0.69	113.35 ^d ± 13.51	6.05 ^b ± 0.42	140.49 ^c ± 17.43
10%	20.55 ^c ± 0.96	135.80 ^c ± 8.61	6.18 ^b ± 0.35	152.21 ^{bc} ± 16.25
15%	29.89 ^b ± 1.92	177.32 ^b ± 8.70	7.30 ^a ± 0.26	163.07 ^{ab} ± 2.72
20%	37.15 ^a ± 1.12	200.47 ^a ± 10.28	8.37 ^a ± 1.42	176.16 ^a ± 2.87

Each value is mean ± standard deviation of triplicates

Means within the same column having the same superscript letter are not significantly different ($p \leq 0.05$)

similar to that one produced from the raw *O. ficus-indica* fruit and total flavonol contents in the extruded products were corresponding to the contents expected for each level of fruit addition. These findings illustrate the thermostability of flavonols against extrusion cooking. Moreover, results illustrated that antioxidant activity of the final snacks produced from the extrusion of rice fortified with *O. dillenii* seed powder increased depending on the concentration of the material added. This result is in agreement with the result reported by Moussa-Ayoub et al. (2015) who found that addition of cactus pear fruit to cereal preparations enhanced the antioxidant activity of the products. Sharma et al. (2012) explained that increase in antioxidant activity of barley extrudates was due to the formation of brown colour pigments from Maillard browning reaction during extrusion processing.

Sensory evaluation of extrudates

The sensory attributes results, like taste, odor, crispness, chewiness, color, pore distribution and surface characteristics of rice based extrudates enriched with different concentrations of *O. dillenii* seed powder are presented in Fig. 1. In general, the sensory attributes of the base formula (0% *O. dillenii* seed powder ‘the control’) were significantly ($p \leq 0.05$) improved by adding *O. dillenii* seed powder. There were clear improvements in all assessed sensory attributes, which significantly increased by increasing the level of *O. dillenii* seed powder up to 15% compared with the control. Adding powder of *O. dillenii* seeds with a level of 20% resulted in significant decreases in taste and odor related to the hay after taste appear. It also led to a significant ($p \leq 0.05$) decrease in all studied properties such as crispness, pore distribution and surface

Fig. 1 Sensory attributes of the rice based extrudates enriched with *O. dillenii* seed powder

characteristics, which are well correlated with functional properties of the resultant extrudates.

Conclusion

The results showed that *O. dillenii* seeds can be used as a useful and valuable raw material for snacks produced by extrusion cooking. The application of the proposed process parameters allows achieving good quality rice snacks enriched with *O. dillenii* seeds. The best acceptability for rice snacks enriched with *O. dillenii* seeds at 15% was observed. Therefore, rice-based extrudates enriched with *O. dillenii* seed powder may be an attractive type of appetizer with increased nutritional properties.

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