Food
Processing & Technology

Morsy, et al,. J Food Process Technol 2015, 6:1
http://dx.doi.org/10.4172/2157-7110.1000408

Research Article | Open Access

Physico Chemical Properties, Antioxidant Activity, Phytochemicals and Sensory Evaluation of Rice-Based Extrudates Containing Dried *Corchorus olitorius* l. Leaves

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Abstract

Jew's mallow (*Corchorus olitorius L.*) leaves powder was added to rice flour at levels of 0% to 5% and extruded in single screw extruder to produce healthy extrudates. Process variables (feed moisture, feed rate, screw speed and temperature) were kept constant. The effects of adding Jew's mallow leaves on functional properties, color attributes, some phytochemicals contents, antioxidant activity and sensory properties of the resultant extrudates were evaluated. Adding Jew's mallow leaves had significant impact on all functional properties and color attributes of the resultant extrudates. It significantly increased the contents of phytochemicals determined. Antioxidant activity of the extrudates measured by DPPH and ABTS assays significantly increased with adding Jew's mallow leaves. Also, the addition significantly enhanced the sensory properties of the extruded products up to 3%. The resultant products had an improved nutritional profile compared with other extruded products being a good source of some phytochemicals and had high antioxidant activity.

Keywords: Jew's mallow; Extrudates; Functional properties; Antioxidant activity; Phytochemicals; Sensory evaluation

Introduction

Nowadays, the light has focused on foods rich in nutraceutical's and functional properties. The consumer's interest has been toward foods with more natural antioxidants, dietary fibers, natural colorants, minerals, vitamins and synthetic additives free, etc. Thus, the consumption of fruits and vegetables and other functional foods is increased. High consumption of fruits and vegetables is associated with reduced the risks of cardiovascular disease and some cancers [1-4]. Studies have indicated that the consumption of fruits and vegetables in childhood protect against cancer in adulthood [5]. Moreover, the low intake of fruits and vegetables has as a consequence the increment of childhood obesity [6]. Additionally, the current style of life, which is characterized by limited free time, has turned consumers to consumption of ready-to-eat foods. Also, children are attracted to many snacks which are particularly tasty and easy to be eaten. Thus, food manufactures have increased the production of ready-to-eat products using many processes, among these; extrusion is a high temperature – short time well established industrial technology.

Extrusion cooking technology is a versatile and time efficient process in food processing. It is characterized by continuous cooking, mixing and forming processing and produced direct expanded materials with high quality [7,8]. During extrusion, food materials are exposed to high temperature, shear force and pressure over a short time [9,10] and they undergo many chemical and structural transformations which affecting product microstructure, chemistry or the macroscopic shape [11,12]. Final products' quality depends on the process conditions [13]. Extrusion has been used to develop various types of snacks mainly from corn meal, rice, wheat flour or potato flour in many shapes and variety of textures [14].

In order to achieve the need for the production of ready-to-eat products with the need for the consumption of high-nutritional value products, health beneficial ingredients are added to the extruded blends. These ingredients include beans, cactus pear, dates, dried broccoli, herbs, legumes, tomato lycopene, etc [15-21]. More needs to be done in terms of producing extrudates with a positive health benefit, especially for children [22]. Few studies focusing on the incorporation of fruit and vegetables to obtain bioactive compound enriched extrudates of acceptable quality. Thus, the objective of the present study was to production of rice extrudates enriched with dried Jew's mallow leaves and studies the functional, physical, antioxidant and sensory properties as well as the phytochemicals content of the resultant extrudates.

Materials and Methods

Materials

Raw materials: Fresh harvested Jew's mallow (*Corchorus olitorius* L.) was purchased from a local market (Ismailia Governorate, Egypt) during August 2013. Green leaves were separated from plant, washed with tap water and then drained and left to dry on a cheese cloth for 15 minutes at room temperature (34 ± 2°C). The leaves were freeze-dried by a vertical freeze-drier (CPERON, FDU-7006, Gyeonggi, Korea) for 36 hours at -70°C. The freeze-dried leaves were ground and stored at 4°C till use.

Rice was purchased from the local market, then ground to get homogenous particle size by using a laboratory mill (Brabender Automat Mill Quandrumat Senior, Germany). The chemical composition of raw materials is shown in Table 1.

Chemicals and reagents: Folin-Ciocalteu's phenol reagent, anhydrous sodium carbonate, gallic acid, aluminum chloride and sodium hydroxide were obtained from Fluka Company. Sodium

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Received October 29, 2014; **Accepted** November 14, 2014; **Published** January 07, 2015

Citation: Morsy NE, Rayan AM, Youssef KM (2015) Physico Chemical Properties, Antioxidant Activity, Phytochemicals and Sensory Evaluation of Rice-Based Extrudates Containing Dried *Corchorus olitorius* l. Leaves. J Food Process Technol 6: 408. doi:10.4172/2157-7110.1000408

Raw material	Moisture content	Protein	Crude fat	Crude fiber	Ash	Available carbohydrates*
Dried Jew's mallow leaves	8.60 ± 0.38	30.06 ± 3.44	6.78 ± 0.37	11.63 ± 0.41	14.62 ± 1.39	36.91
Rice flour	12.90 ± 0.61	10.33 ± 0.80	1.18 ± 0.29	0.23 ± 0.03	0.84 ± 0.20	87.42

Each value is mean ± SD of triplicates

*The available carbohydrates were calculated by difference

Table 1: Chemical composition of raw materials (g 100 g^{-1} dry weight)

nitrite, quercetin, 2.2-diphenyl-1-picrylhydrazyl (DPPH), 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (trolox), potassium persulfate and 2,2´-azino-bis (3-ethylbenzothiazoline–6-sulfonic acid) diammonium salt (ABTS) were obtained from Sigma-Aldrich CO. Methanol, hexane, sulphoric acid, boric acid, petroleum ether and acetone (analytical grade) were from Scharlab CO.

Methods

Sample preparation: Rice grits and Jew's mallow leaves powder were mixed (in 1 kg batches) to the desired ratios: 0 (control), 1, 2, 3, 4 and 5% Jew's mallow leaves/ rice grits. Feed mixtures were adjusted to desired moisture content (16%) by spraying calculated amounts of water and mixing thoroughly for 15 min. The samples were packed in polyethylene bags and kept in the refrigerator overnight to equilibrate the moisture. The samples were brought to room temperature before extrusion cooking.

Extrusion cooking: A Barabender laboratory single-screw extruder (20 DN, Model No. 186501, type 832500) equipped with feeding device (AEV300, NO.141923, type GNF1014/2) to control the feeding device speed, temperature regulators for 2 extruder zones and die head, compressed-air cooled collars controlled by thermostat, a uniformity tapered screw shaft with a 4:1 screw comparison ratio was used. A die rod type 3 mm was chosen. The extrusion conditions (process variables) were selected based on preliminary experiments to determine optimum expansion and extruder operation conditions. The conditions of the extrusion process were: the screw speed was set at 250 rpm. The raw mixtures were feed at a rate of 160 rpm (about 7.2 kg/ h). The feeding, cooking and die zone temperatures were adjusted at 100, 180 and 180°C, respectively. When all zones of the extruder reached to the desired temperature, the ingredients were discharged into the extruder hopper. The resultant extrudates were directly dried in a forced-air oven drier at 100°C for 5 min and allowed to reach room temperature. Immediately after processing, one part of extrudate samples was collected as it is, and the other part was ground (particle size <500 µm). Samples were stored at 4°C in polyethylene sealed bags until analysis.

Chemical composition: The moisture content, crude protein (Kjeldahl method with a conversion factor of 5.70), crude fat (Soxhlet extraction), crude fiber and ash contents were determined according to AOAC [23] methods. The available carbohydrates were calculated by difference (AC= 100 – [protein + crude fat + crude fiber + ash]).

Expansion Ratio determined (ER): The expansion ratio (ER) of the extrudates was calculated according to Chinnaswamy and Hanna [24]. Extrudate diameters were measured with a caliper (Mitutoyo Corp., Japan) and divided by die diameter. Each value was the average of ten readings.

Bulk density: The bulk density of the extrudates was calculated as described by [25] as follow:

$$Density = 4m/ \pi D^2 L$$

Where: m is the mass of a length L of cooled extrudates with diameter D. Ten replicates of extrudates were randomly selected and an average was taken.

Breaking strength (BS): Breaking force index was determined according to the method described by Bourne [26] using Barabender Struct-O-Graph (Model No.8603, OHG, Dusburg). The extrudate samples were resided on two parallel support bars that attached to an elevator plate from that is raised at constant speed to contact a sensor bar mounted above the sample and equidistant between and parallel to the lower knife edges. A strip chart record gives a force–time plot. The equipment was fitted with a 500-cmg spring and a plexi glass beam. The beam travel speed was 9 mm/ sec. The peak height of the resultant recorded curves (as Barabender units) for each sample was taken as a texture measure (Breaking Force Index). Barabender units (BU) were converted to Newton where, 1000 BU= 5 N. Ten measurements were recorded for each sample.

Water absorption and solubility indices: The water absorption index (WAI) was determined according to the method of Anderson et al. [27]: distilled water (5 ml) was added to ground sample (0.2 g) in a weighed centrifuge tube. The tube was agitated for 2 min and then centrifuged for 15 min at 3000 rpm. The supernatant liquid was poured into a tarred evaporating dish. The remaining gel was weighed and the WAI was calculated as:

$$WAI = m_g / m_s$$

Where: m_g is the weight of the hydrated gel (g) and m_s is the weight of sample (g).

The Water Solubility Index (WSI) was determined from the amount of dry solids recovered by evaporating the supernatant from the water absorption test as:

$$WSI = (m_{ds} / m_s) * 100$$

Where: m_{ds} is the weight of dry solids from the supernatant (g) and m_s is the weight of the sample (g). The results presented are the mean values of three replications

Oil absorption index: Oil absorption index (OAI) was determined according to the method of Liadakis et al. [28]: refined corn oil (6 ml) was added to sample (1.0 g) in a graduated centrifuge tube. The tube was agitated for 1 min, left for 30 min and centrifuge for 20 min at 3000 rpm; the volume of the free oil was read. OAI was calculated as:

$$OAI = V_{oil} / m_s$$

where: V_{oil} is the volume of oil absorbed (ml) and m_s is the weight of the sample (g).

The results presented are the mean values of three replications.

Color measurement: The color values of the ground extrudate samples were measured with a Minolta color reader CR-10 (Osaka, Japan). The measurements were displayed in L^*, a^*, and b^* values which represents light–dark spectrum with a range from 0 (black) to 100 (white), the green–red spectrum with a range from -60 (green) to +60 (red), and the blue–yellow spectrum with a range from -60 (blue) to +60 (yellow) dimensions, respectively. Five replicate measurements were performed and results were averaged. The total color change (ΔE) was calculated by using the following equation [29] where L_0, a_0 and b_0 are the control values for the control sample:

$$\Delta E= [(L^* - L_0)^2 + (a^* - a_0)^2 + (b^* - b_0)^2]^{0.5}$$

Determination of Pigments: The β-carotene, chlorophyll a and b contents were determined with the method described by Barros et al. [30] with some modifications as follows: A 200 mg of ground extrudates was vigorously shaken with 10 ml of acetone-hexane mixture (4:6) for 5 min and filtered through filter paper No. 102. The extract was adjusted to 10 ml with volumetric flask. The absorbance of the extract was measured at 453, 505, 645 and 663 nm using a spectrophotometer (6505 UV/ VIS, Jenway LTD, Felsted, Dunmow, UK). Contents of β-carotene, chlorophyll a and b were calculated according to the following equations:

$$\beta\text{-carotene (mg/ 100 ml)} = 0.216 \times A_{663} - 1.220 \times A_{645} - 0.304 \times A_{505} + 0.452 \times A_{453};$$

$$\text{Chlorophyll a (mg/ 100 ml)} = 0.999 \times A_{663} - 0.0989 \times A_{645};$$

$$\text{Chlorophyll b (mg/ 100 ml)} = -0.328 \times A_{663} + 1.77 \times A_{645}$$

and further expressed in mg per 100 g dry weight.

Preparation of total phenolics, total flavonoids and antioxidants extract: The extract for determination the contents of total phenolics and flavonoids and antioxidant activity of the resulted extrudates was prepared according to the method described by Barros et al. [30] with some modifications as follows: one gram of ground extrudate was stirred with 25 ml of methanol at 125 rpm on Orbital Shaker (LAB-LINE Instruments, Inc., USA) for 1 h at room temperature (35 ± 2°C) and filtered through filter paper No. 102. The residue was then re-extracted with 25 ml of methanol. The methanol extracts were combined and stored at 4°C till analyses.

Determination of total phenolics content: Total phenolics content was calculated in the methanolic extracts, according to the Folin-Ciocalteu method with slight modifications [30]. One ml aliquot of the extract was mixed with 5 ml of Folin–Ciocalteu phenol reagent (diluted with water 1:10 v/v) and 4 ml of sodium carbonate (75 g/ L). The tubes were agitated for 30 s and allowed to stand for 60 min at room temperature (35 ± 2°C) for color development. The absorbance was measured at 765 nm by spectrophotometer. A calibration curve (R^2=9998) of gallic acid (0-0.10 mg/ ml) was prepared and tested under similar conditions. The results were expressed as mg of gallic acid equivalents per 100 g of dry weight (mg GAE/ g DW).

Determination of total flavonoids content: Total flavonoids content was determined by the method reported by Barros et al. [30]. Shortly, 0.5 ml aliquot of the extract was mixed with 2 ml of distilled water followed by addition of 0.15 ml of $NaNO_2$ (5%) solution. After 6 min, 0.15 ml of $AlCl_3$ solution (10%) was added and allowed to stand for another 6 min before 2 ml of NaOH solution (4%) was added. The mixture was brought to 5 ml with distilled water. Then the mixture was mixed well and allowed to stand for 15 min. The absorbance was measured at 510 nm. A calibration curve of quercetin was prepared and total flavonoids content was determined from the linear regression equation (R^2= 0.9999) of the calibration curve. The results were expressed as mg quercetin equivalents per 100 g of dry sample.

Determination of DPPH radical-scavenging activity: The antioxidant activity of the extract was determined by DPPH method described by Ravichandran et al. [31] as follows: 0.2 ml of the methanol extract was mixed for 30 s with 3.8 ml of DPPH solution (6×10^{-5} M), and left to react for 30 min, after which the absorbance of the mixture was measured at 515 nm. The DPPH solution without extract was analyzed as a control. The antioxidant activity was calculated as follows:

$$\text{DPPH radical–scavenging activity (\%)} = [(A_{control} - A_{sample})/ A_{control}] \times 100$$

where A is the absorbance at 515 nm.

$ABTS^{•+}$ assay (trolox equivalent antioxidant capacity, TEAC): The ability of the samples extract to scavenge the $ABTS^{•+}$ radical was determined using the trolox equivalent antioxidant capacity (TEAC) assay. The method modified by Rufino et al. [32] was used. $ABTS^{•+}$ radical cations were produced by reacting 7 mM ABTS stock solution with 145 mM potassium persulfate and allowing the mixture to stand in the dark at room temperature for 12 h before use. The $ABTS^{•+}$ solution was diluted with ethanol to an absorbance of 0.700 ± 0.002 at 734 nm. After addition of 100 µl of the sample extract or trolox standard to 4 ml of diluted $ABTS^{•+}$ solution, absorbance was measured after 6 min of mixing. Ethanolic solutions of known trolox concentrations (0-10 µg per ml) were used for calibration (R^2=0.9995) and results were expressed as µmol trolox per gram dry sample.

Sensory evaluation

The sensory evaluation of the resultant extrudates was carried out after processing .Seven properties constitute the overall acceptability: taste (20), crispness (20), odor (15), chewiness (15), color (10), surface characteristics (10) and pore distribution (10) were judged by eight staff members and office workers of Food Technology Department, Fac. of Agric., Suez Canal University, Ismailia, Egypt. The overall acceptability of the samples was calculated from the total score of tested attributes. The grads were given according to the following scale; excellent (86-100), good (76-85), fair (61-75) and poor (50-60) as described by Kramer and Twigg [33].

Statistical analysis

All data were expressed as means ± Standard Deviation (SD). The influence of adding dried Jew's mallow leaves on the studied properties of extrudates was analyzed using analysis of variance (ANOVA) and Duncan's multiple range tests to detect significant differences between samples. Significant differences were defined at $p<0.05$. All analysis was performed using SPSS program (version 17.0 SPSS Inc).

Results and Discussion

Chemical composition of the resultant extrudates

The chemical composition of the Jew's mallow-rice based extrudates is shown in Table 2. The results showed that the incorporation of dried Jew's mallow leaves in extrudate formula significantly increased the protein, crude fat, ash and crude fiber contents of the resultant extrudates. As expected, increasing the levels of Jew's mallow leaves resulted in a significant decrease in available carbohydrate contents of the extrudates. Many studies on the chemical composition of dried Jew's mallow leaves reported that, it contained 22.96 - 35.22% protein, 8.50 – 12.30% crude fiber and 7.18 – 12.00% ash. The leaves are rich in iron, calcium, thiamin, riboflavin, niacin, β-carotene and ascorbic acid. It has demulcent, diuretic, lactagogue, purgative and tonic properties. Eating Jew's mallow leaves regularly helps control blood pressure, cholesterol and lowers the risks of asthma, cancer, diabetes and heart disease [34,35].

Level of dried Jew's mallow leaves (%)	Moisture content	Protein	Crude fat	Crude fiber	Ash	Available carbohydrates*
0 (control)	9.27[bc]	9.35[d]	1.57[c]	0.19[e]	0.83[d]	88.06[a]
1	9.50[a]	10.66[c]	1.78[b]	0.30[de]	0.98[cd]	86.28[b]
2	9.07[c]	11.14[b]	1.79[b]	0.42[cd]	1.12[bcd]	85.53[bc]
3	9.30[b]	11.21[b]	1.82[b]	0.49[bc]	1.40[abc]	85.08[cd]
4	9.13[bc]	11.35[b]	1.86[ab]	0.62[ab]	1.44[ab]	84.73[cd]
5	9.10[bc]	11.67[a]	1.98[a]	0.71[a]	1.73[a]	83.91[d]

Each value is mean of triplicates

*The available carbohydrates were calculated by difference

Means within a column marked with different letters are significantly different at ($p < 0.05$).

Table 2: Chemical composition (g 100 g^{-1} dry weight) of the Jew's mallow-rice based extrudates

Functional properties of the resultant extrudates

The suitability of extrudates for application depends on their functional properties such as expansion, bulk density, water absorption, water solubility and oil absorption indices [36]. Functional properties of the extrudates are, generally, related with the molecular modifications that occur during extrusion cooking process.

Expansion Ratio (ER) and Bulk Density (BD)

Expansion ratio is an important characteristic of extrudates that greatly affects the consumer acceptability. Results presented in Table 3 showed that, incorporation of dried Jew's mallow leaves insignificantly reduced the expansion values of the extrudates up to 4% compared to the control. Higher levels of dried leaves (5%) resulted in significant reduction of the expansion. Expansion takes place when the material under heat is forced through an extruder die; water vaporizes and the resulting simultaneous vapor flash-off expands the starch content, producing a porous, sponge-like structure in the extruded product. Expansion degree of the extrudates is closely linked to the size, number and distribution of air cells within the material [37]. Maximum expansion ratio was obtained for rice flour (control, Table 3) due to the higher starch and lower fiber and fat contents. Decreasing the amount of starch in the blends and increasing the concentration of protein and fiber through addition of dried Jew's mallow leaves, less expanded extrudates were formed. This phenomenon can be attributed to the interaction between these components and starch, as well as to the reduced elasticity due to the presence of proteins and fibers [38]. Fibers may bind water more strongly than starch, inhibiting water loss at the die and reducing its ability for expansion. Yanniotis et al. [39] observed that the degree of gelatinization affects the degree of expansion. It is probable that powders, high in fiber content, have competed for moisture during the extrusion process affecting the degree of gelatinization and therefore the degree of expansion.

The bulk density of the extrudates significantly ($p < 0.05$) increased with Jew's mallow leaves addition, especially at high levels (Table 3). There is solid evidence that if high fiber, high protein materials are added to starch based extruded products, the density is expected to increase [40]. Similar findings were reported by Dehghan-Shoar et al. [41] and Potter et al. [42] who incorporated tomato paste powder and dried fruits respectively into formulations for extrusion. The findings were attributed to the presence of sugar and fiber that absorb moisture and affect the expansion capability of the extrudates. Fiber can also rupture cell walls and prevent air bubbles from expanding to their maximum level, resulted in an increase in density [43]. Bulk density has been observed by Maga and Kim [44] to be related to expansion, with increasing expansion decreasing product density. The results obtained in this study (Table 3) concur with these observations. In this study a negative correlation (R^2=-0.805) was found at significant ($p<0.05$) level between expansion and bulk.

Water absorption and solubility indices

The Water Absorption Index (WAI) measures the amount of water absorbed by starch and can be used as an index of gelatinization. Extrusion temperature and feed moisture content are affect gelatinization during extrusion cooking and consequently the WAI. The modifications in polymers structure occurred during extrusion are considered to be the result of mechanical degradation, although thermal degradation is known to occur during prolonged heating processes [45].

The water solubility index (WSI) is a parameter that can be used as an indicator for the degradation of molecular compounds and measures the degree of starch dextrinization during extrusion [46,47]. The incorporation of dried Jew's mallow leaves significantly ($p<0.05$) influenced the WAI and WSI. A clear trend of WAI and WSI was not found with Jew's mallow/ rice flour ratio (Table 3). The increase of dried Jew's mallow leaves increased protein and crude fiber contents of the resultant extrudates (Table 2). The WAI depends on availability of hydrophilic groups which bind water molecules and on the gel forming of macromolecules [48]. Although protein has hydrophilic groups such as –OH, -NH_2, -COOH and –SH, the protein led to loss of hydration capacity of proteins by formation of inter- and intra-molecular protein bonds with amylo se and amylopectin [49]. Thus, the addition of proteins in extrudates can decrease starch molecular degradation [50]. Besides, all the macromolecular modifications during extrusion cooking are affected by the shearing forces developed in the extruder barrel. The shear rate depends on the specific mechanical energy, a system parameter which is affected by extrusion conditions and material characteristics [51-53]. The incorporation of Jew's mallow leaves in extrudates increased the protein and fiber contents, so it was expected to increase the WAI and decrease the WSI, which was found in some samples. But the addition of Jew's mallow leaves at 1 and 2% had opposite effect (Table 3).

Oil Absorption Index (OAI)

The increase in Jew's mallow/ rice flour ratio decreased the OAI of the resultant extrudates (Table 3). Rice extrudate (control) showed the highest value for OAI (2.80 ml/ g). The incorporation of high-protein materials in the extrudates lowered the OAI. This trend has been reported for bean and lentil/ corn extrudates [54]. Kinsella explained the mechanism of oil absorption as a physical entrapment of oil, whereas many authors [55-57] related oil absorption capacity 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. Different protein concentrations, amounts of

Level of dried Jew's mallow leaves (%)	ER	BD (g 100 ml^{-1})	BS (N)	WAI (g g^{-1})	WSI (%)	OAI (ml g^{-1})
0 (control)	3.28^{a}	36.53^{de}	4.37^{a}	9.01^{abc}	23.00^{c}	2.80^{a}
1	3.26^{a}	33.69^{e}	2.59^{b}	8.70^{bc}	36.00^{ab}	2.80^{a}
2	3.27^{a}	37.61^{cd}	2.70^{b}	8.34^{c}	40.33^{a}	2.70^{a}
3	3.26^{a}	40.76^{bc}	2.87^{b}	9.71^{a}	24.00^{bc}	2.70^{a}
4	3.25^{a}	43.23^{ab}	2.69^{b}	9.66^{a}	23.17^{c}	2.20^{b}
5	3.04^{b}	46.79^{a}	2.80^{b}	9.28^{ab}	20.50^{c}	2.10^{b}

Means within a column marked with different letters are significantly different at ($p < 0.05$).

Table 3: Functional properties of the Jew's mallow-rice based extrudates

nonpolar amino acids, different conformational features and starch-protein-lipid binding could be reasons for different oil retaining characteristics.

Breaking Strength (BS)

The breaking strength is taken as an indicator for the quality of texture. Results in Table 3 showed that the incorporation of Jew's mallow leaves significantly decreased the BS of the resultant extrudates compared to the control sample. No significant changes were observed with increasing the level of incorporation. Chauhan and Bains [56] mentioned that, incorporation of different protein concentration with rice flour increased the crispness and decreasing breaking strength of the extruded product. Similar trend was obtained by [58,59].

Color attributes of the resultant extrudates

Color is an important parameter of quality index of food for universal acceptability [60]. In recent days market for application of synthetic colorants has decreased in favor of natural colorants. Fruits and vegetables are good sources of natural colorants. The L^*, a^*, b^* and ΔE values are commonly used as an index to report the color quality. Results presented in Table 4 showed that, the color parameters of the resultant extrudates significantly changed with the incorporation of dried Jew's mallow leaves. The $-a^*$ values correlated with the Jew's mallow content, thus it was higher in products containing 4% (-3.04) and 5% (-3.44). On the other hand, products with higher $-a^*$ values were darker and had lower L^* and higher ΔE values (Table 4). The color of the resultant extrudates changed from white in control sample to greenish in the extrudates containing 5% Jew's mallow leaves. These results are in good agreement with those obtained by El-Saies et al. who found that, extrudates contained 1.5% Jew's mallow had pale greenish color.

Phytochemicals and antioxidant activity of the resultant extrudates

Phytochemicals (natural antioxidants) provide health benefits associated with their ability to prevent damage due to biological degeneration. Levels of individual antioxidants in food do not necessarily reflect their total antioxidant capacity, which could also depend on synergic and redox interactions among the different antioxidant molecules (phytochemicals, vitamins, minerals and fiber) present in the food. As Jew's mallow leaves had high contents of phytochemicals (such as chlorophylls a and b, β-carotene, total phenolics and flavonoids) and exhibited high antioxidant capacity [61], results presented in Table 5 showed that, incorporation of Jew's mallow leaves in extrudates had a positive impact on the levels of chlorophylls a and b, β-carotene, total phenolics and flavonoids contents. The content of these phytochemicals significantly increased with increasing of Jew's mallow level. Similar trend was observed with the antioxidant activity of the resultant extrudates measured by DPPH and ABTS assays, which significantly increased from 3.68% and 110.40 μ mol trolox per 100 g for the extrudate without addition (control) to 8.31% and 217.62 μ mol trolox per 100 g for the extrudates with 5% Jew's mallow, respectively. Among the phytochemicals, phenolic compounds are reported to be the main contributor of antioxidant activity in plant extracts due to their higher value in total content [62], interaction and redox property of an individual or combination of their diverse chemical structures [63] and their synergistic effectiveness as hydrogen donors, reducing agents and free radical scavengers [64,65]. The health properties of phenolic compounds have been extensively studied from the epidemiological point of view by directly searching for their effect on enzymatic systems and/ or their effect on physiological functions. Based on the approach of assigning a health property to these compounds, food functionality is going to depend on their content, intake and bioavailability [66]. Bioavailability of phenolic compounds can be affected by differences in cell wall structures, location of glycosides in cells and binding within the food matrix, which are directly related to food processing conditions [67].

Within the last years, flavonoids have been highlighted as possible chemo-preventive dietary agents against cancer. They have shown ability to absorb ultraviolet radiation protecting DNA. They have also shown protective effect on bleeding and capillary fragility and antimicrobicide. Most of health promoting effects of flavonoids is related to their antioxidant properties and to synergistic effects with other antioxidants. Also, it may result from the interactions between flavonoids and metal ions especially iron and copper [68]. The American Cancer Society (ACS) recommends a 100 mg per day as an adequate amount for the prevention of cancer and degenerative illness [69]. From results in Table 5, serving of 100 g per day from the rice extrudate containing 2% Jew's mallow leaves will be covering the ACS recommendations from flavonoids intake.

Besides its provitamin A activity, β-carotene has other physiological functions, such as cell-to-cell communication, immunomodulatory effect and ultraviolet skin protection. Chlorophylls are the most abundant pigments in nature. Lanfer-Marquez et al. [70] found that, chlorophyll a showed the weakest antioxidant activity among all greenish pigments. The metal-free counterpart pheophytin a, presented a relatively high protection against oxidation. Derivatives b (pheophorbide b and pheophytin b) presented higher antioxidant capacity than derivatives a according to the presence of the aldehyde group in place of the methyl group. In contrary, Endo et al. [71] found that chlorophyll a had the strongest antioxidant activity followed by BHT, chlorophyll b, pheophytin a and pheophytin b and the four pigments presented a linear dose-dependent response. The conflicting results in measurements of antioxidant activity for the same compound referred to some factors such as the physical structure of the test system, the nature of the substrate for oxidation and the analytical method used [72].

Level of dried Jew's mallow leaves (%)	L^*	a^*	b^*	ΔE
0 (control)	84.72 ± 1.23^a	+0.44 ± 0.21^a	10.88 ± 0.76^e	-
1	73.66 ± 1.77^b	-2.22 ± 0.26^b	20.76 ± 0.57^c	15.07^d
2	68.98 ± 1.39^c	-2.26 ± 0.51^b	23.40 ± 1.14^a	20.29^c
3	63.64 ± 1.15^d	-2.64 ± 1.73^{bc}	22.16 ± 2.08^b	24.11^b
4	63.02 ± 2.13^d	-3.04 ± 0.69^{bc}	21.10 ± 1.66^c	24.24^b
5	60.58 ± 1.20^e	-3.44 ± 1.61^c	19.60 ± 0.60^d	25.96^a

Each value is mean ± SD of ten replicates

Means within a column marked with different letters are significantly different at ($p < 0.05$).

Table 4: Color attributes (L^*, a^*, b^* and ΔE) of the Jew's mallow-rice based extrudates

Level of dried Jew's mallow leaves (%)	Phytochemical content					DPPH (%)	ABTS (μmol trolox 100 g^{-1})
	Chlorophyll a	Chlorophyll b	β-carotene	Total phenolics	Total flavonoids		
0 (control)	nd	nd	nd	9.10^d	72.36^e	3.68^d	110.40^d
1	1.21^e	0.46^e	0.49^e	13.40^c	93.24^d	5.70^c	142.39^c
2	1.90^d	0.81^d	0.69^d	14.44^{bc}	104.86^{cd}	6.02^c	159.21^{bc}
3	3.53^c	1.61^c	1.11^c	15.44^{bc}	114.57^{bc}	7.42^b	166.94^{bc}
4	4.51^b	2.03^b	1.57^b	16.09^b	129.78^b	8.31^b	170.01^b
5	5.57^a	2.35^a	1.80^a	30.81^a	166.73^a	10.30^a	217.62^a

nd= not determined

Each value is mean of triplicates

Means within a column marked with different letters are significantly different at ($p < 0.05$).

Table 5: Phytochemicals content (mg 100 g^{-1} dry weight) and antioxidant activity of the Jew's mallow-rice based extrudates

Level of dried Jew's mallow leaves (%)	Taste	Odor	Crispness	Chewiness	Color	Pore distribution	Surface characteristics	Overall acceptability and grade
0 (control)	13.75^{bc}	13.50^a	13.75^{bc}	10.50^{cd}	6.00^b	6.88^{ab}	6.50^b	70.88^b Fair
1	15.50^{ab}	13.25^a	16.75^a	11.75^{ab}	7.50^a	7.63^a	7.75^a	80.13^a Good
2	15.75^a	13.00^a	16.75^a	12.75^a	8.38^a	8.00^a	8.00^a	82.63^a Good
3	15.00^{ab}	12.75^a	16.00^{ab}	11.25^{bc}	8.25^a	7.50^a	8.25^a	79.00^a Good
4	12.75^{cd}	12.25^a	15.00^{ab}	9.50^d	7.50^a	6.75^{ab}	6.75^b	70.50^b Fair
5	11.75^d	12.50^a	11.50^c	8.00^e	6.00^b	6.00^b	5.75^b	61.50^c Fair

Each value is mean of eight replicates

Means within a column marked with different letters are significantly different at ($p < 0.05$).

Table 6: Sensory evaluation of the Jew's mallow-rice based extrudates

In all resultant extrudates the levels of measured phytochemicals were positively correlated to both DPPH and TEAC antioxidant activities. The correlations coefficient were 0.9551 and 0.7919, 0.9129 and 0.7276, 0.9394 and 0.7537, 0.7974 and 0.9358, 0.9722 and 0.9630 for chlorophyll a, b, β-carotene, total phenolics and total flavonoids contents with DPPH and TEAC antioxidant activities, respectively (data not shown).

Sensory attributes of the resultant extrudates

Whilst the nutritional properties of the products are a key consideration, the extrudates need to have satisfactory organoleptic properties, which are important for its acceptability. Dehghan-Shoar et al. reported that the acceptability of the extrudates depends mainly on the physical and sensory attributes, which are usually measured as density, expansion, taste and appearance. These properties are related to the number and size of air cells formed during extrusion which are depend on the proportion and type of the starch. Results are presented in Table 6 showed that the fair (70.88) sensory attributes of the base formula (0% Jew's mallow) were significantly (p<0.05) improved by adding dried Jew's mallow leaves. There were clear improvements in all sensory attributes tested, which significantly increased by increasing the level of dried Jew's mallow leaves up to 3% (79.00, good) compared with the control. Adding Jew's mallow leaves over 3% resulted in significant decrease in taste and odor related to the hay after taste appear. It also, led to significant (p<0.05) decrease in all studied properties such as crispness, pore distribution and surface characteristics, which are well correlated with functional properties of the resultant extrudates.

Conclusion

Most types of snacks have been shown as a poor diet. Improvement the diet of children highlighted the nutritional content of snack products. In this study, rice extrudates enriched with dried Jew's mallow leaves were produced to enhance the healthy snack food production. The produced extrudates have the potential of replacing traditional snacks that are low nutrient and helping to solution of childhood obesity and disorders. Incorporation of Jew's mallow leaves in rice extrudates had an impact on the functional properties of the resultant extrudates that contribute to the organoleptic properties. In addition it has been seen that the produced extrudates were good source of phytochemicals and had high antioxidant capacity compared to extrudates without Jew's mallow leaves.

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Citation: Morsy NE, Rayan AM, Youssef KM (2015) Physico Chemical Properties, Antioxidant Activity, Phytochemicals and Sensory Evaluation of Rice-Based Extrudates Containing Dried *Corchorus olitorius* l. Leaves. J Food Process Technol 6: 408. doi:10.4172/2157-7110.1000408