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Development of Nutritious Extruded Snacks

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Abstract: Mixtures of cereals and legumes lead to products with a better content of protein with a high biological value. Sweet lupine flour had the highest protein, fat and fibre content (39.37, 3.08 and 3.92% respectively), while sweet potato flour had the highest ash and carotene content (4.03% and 32.51 mg/kg). The product prepared from extruding broken rice, sweet potato flour and sweet lupine flour had an increased nutritional value. Adding 10% sweet potato flour resulted in a significant increase in fiber, ash and total carotenoids. While increasing amounts of sweet lupine resulted in a gradual increase in the values of protein, fat, fiber and ash. There was a decrease in the EI, WAI and WSI values as the concentration of lupine increased. It could be noticed that consuming fortified snacks could provide children with part of their daily requirements of protein, dietary fiber, carbohydrate, calcium, iron and zinc.

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1. Introduction

Mixtures of cereals and legumes lead to products with a better content of protein with a high biological value. While legumes are deficient in sulfurous amino acids and rich in lysine, cereals on the other hand are deficient in lysine and relatively rich in sulfur-containing amino acids. Therefore, cereals and legumes are considered complementary offering advantages in the nutritional quality **(Teba *et al.*, 2009).**

Lupine (*Lupinus spp.*) has been cultivated for approximately 4000 years and is a legume that has a rich and varied nutritional composition **(Van Barneveld, 1999)**. However, lupine is not widely used in human food due to the presence of anti-nutritional factors that must be removed before consumption of this grain **(Botaro, 2010, Monteiro *et al*., 2010).** Despite the actual fact that the white lupine variety (also called *Lupinus albus* or sweet lupine) has undergone modifications over time to reduce the content of anti-nutritional factors and alkaloids. Application of heat is one of the main methods used to remove these anti-nutritional factors**,** and different techniques of heat application, such as extrusion, hot-air roasting, hot-air steaming, baking and microwaving, can be used. (**Botaro, 2010 and Monteiro *et al*., 2010).**

Sirtori *et al.* (2004) research work has proved that consumption of lupin-based foods leads to reduction in low-density lipoprotein levels. Other work has proved lupine to reduce plasma cholesterol and triglycerides (**Arnoldi, 2008**) and blood pressure (**Lee *et al.*, 2009**). The addition of lupin fiber to the diet provided favorable changes in serum lipids suggesting this novel ingredient is useful in the reduction of coronary heart disease risks (**Hall *et al.*, 2005**). **Diaz *et al*., (2017)** reported that it is possible to produce corn-based extrudates containing up to 20% lupine without any substantial changes in sectional expansion and stiffness. **Wandersleben *et al.* (2018**) reported that 90% of the individuals to like and like extremely lupine supplemented bread.

Broken rice is defined as the by-product of rice milling industry. Also, rice flour prepared from rice broken may be used as important ingredient for several ready–to-eat breakfast cereals and snacks. **Omran and Hussien (2015**) stated the low commercial value of broken and chalky grains, could be used in suitable food products.

Sweet potato (I*pomoea batatas L.*) is an important alternative source of carbohydrates and attains the fourth place after rice, corn and cassava. Presently, this crop is taken into account as having low economic value however it's significant social importance. It is most versatile for snack food; however, it's used as staple food or as a rice substitute in several countries. Sweet potato features a massive potential to be used as food in developing nations with restricted resources attributable to short maturity time, ability to grow under various weather conditions, and on less fertile soils (**Zuraida, 2003**). Sweet potato flesh may be white, creamy, yellow, orange, or purple. Orange, white, and creamy ones are the most commonly grown and eaten **(Bovell-Benjamin, 2007 and Sandhill Preservation Center, 2010).**

Sweet potatoes are a nutritious food, low in fat and protein, but rich in carbohydrates. Tubers and leaves are good sources of antioxidants **(Teow *et al*, 2007),** fiber, zinc, potassium, sodium, manganese, calcium, magnesium, iron, and vitamin C **(Antia *et al.*, 2006)**. Orange flesh sweet potatoes are also a very good source of vitamin A **(Teow *et al.*, 2007 and Wu *et al.*, 2008)**. Also, **Sebben *et al.* (2017)** reported that the type of drying has no effect on the nutrients.

The objective of this study was to prepare healthy extruded snacks by the replacement of broken rice flour with sweet potato flour and sweet lupine flour to increase the nutrients. Also could be evaluation of their chemical, physical and sensorial properties.

2. Materials and Methods

Raw materials

Sweet potato (SP), sweet lupine (SL) (*Lupinus albus*) and broken rice (BR) were purchased from the local market at Saudi Arabia.

Preparation of samples

Sweet potato samples (orange fleshed) were washed, peeled and cut into thin slices. Slices were directly immersed into 1% NaCl solution, and then, immersed in a solution containing sodium meta-bisulphite (1%) and citric acid (0.5%) for 30 min **(Shih *et al*, 2009).** Sweet potato slices were dried at 55°C. The dried slices were milled into flour and sieved (315 μm) into powdered form. The flour was then packed into polyethylene bags and kept at –20°C for further analysis.

Lupine seeds were soaked in water for 2 days with many changes of water then the soaked seeds were air-dried for three days at temperature (25 ºC ±2). The air-dried seeds were milled in laboratory to pass through a 60-mesh sieve.

Broken rice was ground to get homogenous particles size of (400-600) micron by using a laboratory mill (Brabender Automat Mill Quandrumat Senior, Germany).

Extrusion process

The broken rice flour was partially replaced by 10% sweet potato (F2) and sweet lupine flour at levels of 2.5, 5, 7.5 and 10% (F3-F6). The extrusion process was carried out using a Barabender Laboratory twin-screw extruder. The extrusion conditions for zones temperatures were 90, 130 and 200°C for the screw speed was 249 min^{-1} and for the feeding screw speed was 160 min^{-1}. The resultant extrudates were directly dried in an air forced drier oven at 110°C for five min and left to equilibrate at the room temperature. Samples did not contain any artificial flavors or colors.

Chemical analysis

Sweet potato, lupine, rice flour and snacks were analyzed for its moisture, ash, protein and fat according to the standard **AACC (2000)** methods. Nitrogen content as estimated by Micro-Kjeldhal method and was converted to protein by using a factor of 6.25. Carbohydrates are determined by difference. Total calories were calculated by the formula of **James, 1995** as follows:

Total calories = Fat x 9 + Protein x 4+ Total carbohydrate x 4

Determination of total carotenoids

Total carotenoids were determined in raw materials and cookies using the method outlined by **Santra *et al.* (2003**). A standardization curve was made of familiar quantities of β-carotene and was expressed as mg/kg on dry weight basis.

Determination of minerals content

Minerals content were determined in the diluted solution of ash raw materials and their blends using the atomic absorption spectrophotometer (3300 Perkin-Elme) as described in by **AOAC (2012).**

Color measurement

Sweet potato flour, sweet lupine powder, rice flour and snacks were measured with a Hunter Lab Colorimeter (Mini Scan XE Plus, Reston, VA) according to the method described by **Abd El-Hady *et al.* (2002)** and recorded in the L^* a^* b^* c^* h color system. Numerical total color difference (ΔE) was calculated as follows: $\Delta E=[(L-L_0)^2+(a-a_0)^2+(b-b_0)^2]^{½}$.

Physical properties

Expansion ratio was determined as method described by **Halek and Chang (1992)** Bulk density was determined as described by **Rahman (1995**). Water absorption index (WAI) and water solubility index (WSI) were determined as outlined by **Anderson *et al.* (1969)** and **Damardjati and Luh (1987).** Water and oil holding capacity were performed according to the method of **Beuchat (1977).**

Sensory evaluation of products

The sensory evaluation was carried out in order to get consumer response for overall acceptability of the 2.5%, 5%, 7.5% and 10% sweet lupine flour incorporated snacks compared to the control snacks. Panelists from Food Technology Research Institute, Agricultural Research Center evaluated texture, taste, color, and overall acceptability according to the method described by **Ibrahim *et al.* (2012).**

Statistical analysis

Statistical analyses were carried out by SPSS (ver.16) program. Data were expressed as means ± SEM and also one-way analysis of variance followed by Duncan's tests was performed. **(SPSS, 2000)**.

3. Results and Discussion

Physico-chemical analysis of raw materials:

Sweet lupine flour had the highest protein, fat and fiber content (39.37, 3.08 and 3.92% respectively), while sweet potato flour had the highest ash content (4.03%). Our results for broken rice flour were partly in agreement to **Dahab (2006)** who reported that broken rice flour had 7.68% proteins, 0.27% crude fiber, 0.36% ash, and 90.81% carbohydrates. While **Omran and Hussien (2015)** reported water and oil holding capacities for rice flour to be 176.49 and 94.3%.

Fat content of sweet potato was in range to that of **Srivastava *et al.* (2012**). Protein content in sweet potato flour was 3.77%. Carbohydrate contents of sweet potato flour (91.41 and 15.49%, respectively) were near to **Singh *et al.* (2008)** and **Ahmed *et al.* (2010)**.

As for carotene content, the highest content of total carotenoids was observed in sweet potato flour (32.51 mg/kg), followed by sweet lupine. Results agree with **Omran and Hussien (2015) and Bulda *et al*. (2008)**.

Mineral content of sweet lupine are slightly lower than those reported by **Suliburska *et al.* (2008).** The variation in chemical composition could also be attributed to variety variations and different growing conditions (such as geographic, seasonal differences weather conditions and soil characteristics), and extent of foreign materials, impurities, varieties, different processing and measuring methods (**Taher-Maddah *et al.*, 2012).**

Both water and oil binding capacity increased with increasing the protein content. Table (1) presents water and oil holding capacity; it is clear that sweet lupine flour had the highest WHC (256.63%) followed by sweet potato flour which had a WHC of 243.13% and finally broken rice flour which had 176.49% WHC. Water holding capacity of sweet potato flour was in the range as observed by **Eleazu and Ironua (2013**) who reported it to be from 149 to 471%. As for results of WHC of sweet lupine, they agree with work by **Mahmoud *et al.* (2012).** Moreover, **Cano and Ancos (2005)** reported that proteins forming a three-dimensional network structure to produce a matrix capable of holding significant amounts of water in sweet lupine flour. While for OHC, sweet lupine flour had the highest value of 110.85% flowed by broken rice flour which had 96.30% and finally sweet potato flour which had a value of 85.35%. The results of sweet lupine, they agree with work by **Mahmoud *et al.* (2012). Sathe *et al.* (1982)** suggested that the increased oil absorption of the sweet lupine flour may be due to the lipophilic nature of lupine seed proteins. The presence of several non-polar side chains may bind the hydrocarbon chains of fats, thereby resulting in higher absorption of oil. While **Osundahunsi *et al.* (2003)** found that oil absorption capacities, in sweet potato flour, to be low for both red and white sweet potato flours. The mechanism of fat absorption is attributed principally to the physical entrapment of oil and also the binding of fat to the polar chain of protein.

Lupine flour was characterized as bright yellow with green tones (a value is negative). Color of lupine flour agree with work by **Mohamed and Rayas-Duarte (1995)** who suggested that the bright yellow color of the whole flour might have applications in substituting egg yolks or yellow dyes in food products. L and h values of broken rice flour were more than those of sweet potatoes. On the opposite hand, sweet potato had the highest values in a, b and c, and b value of sweet potato. The color values in sweet potato and rice flour were close to those reported by **Ali *et al*. (2012)** and **Torbica *et al.* (2012)**, respectively.

Physical properties of extruded snacks

Expansion ratio (ER) of the extrudates was defined as the ratio of the diameter of the extrudate to the diameter of the extruder die (**Yu *et al.*, 2009**). The samples containing sweet lupine flour showed a lower degree of expansion and more irregular shapes than the control sample. Some changes occurred in the appearance of the sample with 10% sweet lupine flour because this sample had high protein content and low starch content. The control, 2.5%, 5%, 7.5% and 10% samples had expansion ratio of 3.19%, 3.11%, 3.00%, 2.95% and 2.40%, respectively. A reduction in the rate of expansion was observed as sweet lupine flour was added to the extrudate samples. There was no significant difference between the sample with 2.5 % sweet lupine flour and the control. However, there was a significant reduction in this ER values to 3%, 2.95 and 2.42% when the sweet lupine flour content increased up to 10%. Reduction in the amount of rice flour in the mixture led to a reduction in expansion ratio. **Kokini *et al*. (1992)** referred this reduction to the presence of protein which reduces expansion. Also, the insignificant effect in expansion due to changes in feed composition could be attributed to the uniform particle size of the raw samples. **Colonna *et al.* (1989)** reported that particle size of materials fed into a single screw extruder affects expansion.

Table (1): Presents of physico-chemical analysis of sweet potato, sweet lupine and rice flour.

Physico-chemical	**Broken Rice Flour**	**Sweet Potato**	**Sweet Lupine**
Moisture	9.42±0.12	6.25±0.10	8.40±0.12
Protein	7.71±0.15	3.97±0.23	40.37±0.10
Fat	0.22±0.10	0.74±0.09	3.18±0.04
Ash	0.68±0.09	2.13±0.15	1.25±0.07
Fiber	0.25±0.11	4.40±0.12	3.99±0.15
Carbohydrate	91.36±0.21	91.41±0.19	51.43±0.23
Carotene (mg/kg)	ND	32.61±0.11	2.7 ±0.10
Minerals (mg/100g)			
Ca	11.95 ±0.04	133.10±0.08	19.03±0.20
Fe	0.54 ±0.13	3.64±0.11	4.325±0.15
Zn	2.60 ±0.08	4.30±0.04	3.818±0.19
P	ND	1.9±0.10	4.01±0.07
Mg	ND	0.65±0.07	122.56±0.04
Physical properties			
WHC	171.49±0.03	240.13±0.02	256.63±0.25
OHC	96.30±0.02	85.35±0.06	110.85±0.29
Color			
L	74.35±0.01	68.93±0.04	82.78±0.03
a	-0.80±0.05	2.44±0.03	-1.98±0.08
b	8.33±0.04	22.56±0.05	21.33±0.04
c	8.22±0.04	22.69±0.05	12.52±0.07
h	95.69±0.05	83.75±0.02	92.89±0.05

Values are means of three replicates ±SD, on dry weight basis. ** Total carbohydrates were calculated by difference. ***L (lightness with L = 100 for lightness, and L = zero for darkness), a [(chromaticity on a green (-) to red (+)], b [(chromaticity on a blue (-) to yellow (+)], c (color saturation), h [(hue angle where 0°=red to purple, 90° = yellow, 180°=bluish to green and 270° = blue scale. ND = not detected.

Regarding the ratios of absorption and solubility in water (WAI and WSI, respectively) the control sample showed significantly higher values for both WAI (9.55) and WSI (23.49) compared to the other samples. The ratios obtained for the 10% sweet lupine flour sample were the lowest (7.19 and 16.63 for WAI and WSI, respectively) than those for 2.5% sweet lupine flour (8.54 and 22.27 for WAI and WSI, respectively). Samples with higher starch content showed higher values of WAI and WSI, and these values decreased as the concentration of sweet lupine flour increased. Water absorption depended on starch content and extruded starch readily absorbed water to form a paste at room temperature. This is a usual trend in extruded starchy materials as stated by **Colonna *et al.* (1989**).

Table (2): Physical properties of extruded snacks

Sample	**Expand Ratio**	**Water Absorption Index (WAI)**	**Water Solubility Index (WSI)**	**Bulk Density (weight/volume)**
F1	3.21±0.11^{a}	9.73±0.04^{a}	23.74±0.03^{a}	77.31±0.19^{f}
F2	3.19±0.19^{a}	9.55±0.03^{b}	23.49±0.09^{b}	78.11±0.04^{e}
F3	3.11±0.09^{a}	8.54±0.11^{c}	22.27±0.04^{c}	80.12±0.07^{d}
F4	3.00±0.11^{b}	8.11±0.07^{d}	20.85±0.12^{d}	83.89±0.09^{c}
F5	2.95±0.03^{b}	7.79±0.19^{e}	18.75±0.03^{e}	87.30±0.11^{b}
F6	2.42±0.04^{c}	7.19±0.04^{f}	16.63±0.06^{f}	90.10±0.03^{a}

Values are means of three replicates ±SD.

Bulk density plays an important role in product appearance and overall satisfactoriness of the product and is a crucial physical property in planning appropriate packaging materials. The physical properties of the extruded rice snacks are shown in Table (2). Increase in sweet lupine flour level in extruded snacks causes an increase in the bulk density values. The increase in bulk density with increasing sweet lupine flour level could be, as reported by **Yağcı and Göğüş (2008),** due to the addition of increasing amounts of fiber and protein to the blend which might affect the extent of starch gelatinization and the rheological properties of the melted material in the extruder. While **Lue *et al.* (1991**) explained that the increasing bulk density, caused by less expansion and more impact, was due to the presence of fiber particles which tended to rupture the cell walls before the gas bubbles had expanded to their full potential. **Camire and King (1991))** explained that the non-starch polysaccharides in fiber might bind water more tightly during extrusion than protein and starch did. This binding might inhibit water loss at the die and reduce expansion, and thus probably increase bulk density in his study on the protein and fiber supplementation effects on extruded cornmeal snack quality.

Color measurements

Another important parameter in assessing the quality of the extruded product is the color coordinates of the samples the extrusion process. Table 3 shows the values of the color scale parameters for the extrudates.

Table (3) shows the effect of orange sweet potato flour and sweet lupine flour addition on the color of extruded snacks. The *L*, a* and b** values varied significantly with addition of orange sweet potato flour and lupine flour. *L** values, which correspond to whiteness or lightness, decreased with the addition of orange sweet potato flour to broken rice flour. The decrease in *L** value is possibly due to orange color of the sweet potato. We also observed a significant increase in *L** with increased lupine concentration in the extruded samples ranging from 61.32, for samples containing only 10% sweet potato flour, to 79.99 in the samples containing 10% sweet lupine flour.

The increase in the sweet lupine flour to extruded snacks decreased *a** values which correspond to redness. The values decreased significantly from 9.55 for sample containing only 10% sweet potato flour, to 7.24 in the samples containing 10% sweet lupine flour. While the *b** values which represent yellowness were the least affected with the addition of 10% sweet lupine flour to extruded snacks. Higher *b** values comparatively indicate the samples more yellowish, which was observed in samples with 10% lupine. This may be explained by higher b* values (21.33) of sweet lupine and this sample had the highest concentration of lupine. Our results agree with work by **Oliveira *et al*, 2015** on rice-lupine snacks.

The *c** values were lower for the lupine containing samples and higher for the sample with sweet potato and rice only. These indicate that the control sample had higher color intensity than the other samples. The *h** values indicate the tones of the samples as follows: values near to zero, 90, 180 and 270 indicate a red, yellow, green and blue hue, respectively. Thus, the values found for all samples urged that the yellow tint increased because the concentration of lupine within the extruded samples increased.

According to **Teba *et al.* (2009),** the color formation during the extrusion process depends on the temperature of the heat treatment and is directly related to the composition of the formulation. **Borba *et al.* (2005)** referred the changes in colors observed in extruded products to caramelization or the Maillard reaction, especially in materials that have relatively high levels of reducing sugars that are favored by process conditions browning occurring in the extruded product.

Table (3): Color parameters of extruded snacks

Samples	***L***	***a***	***b***	***c***	***h***	**ΔE**
F1	84.70±0.05f	3.05±0.09a	12.15±0.25f	32.25±0.07[a]	60.95±0.07[f]	-
F2	61.32±0.07[e]	9.55±0.05[b]	15.90±0.03[e]	30.99±0.09[b]	64.89±0.02[e]	24.55±0.02[a]
F3	69.57±0.02[d]	8.68±0.09[c]	16.25±0.06[d]	28.79±0.01[c]	68.92±0.09 [d]	16.66±0.05[b]
F4	75.87±0.06[c]	7.75±0.07[d]	17.11±0.07[c]	27.65±0.05[d]	70.12±0.03[c]	11.16±0.01[c]
F5	77.12±0.09[b]	7.51±0.03[e]	17.97±0.03[b]	25.89±0.04[e]	74.98±0.05[b]	10.79±0.07[d]
F6	79.99±0.08[a]	7.24±0.06[f]	18.76±0.11[a]	23.53±0.03[f]	79.35±0.02[a]	9.13±0.04[e]

*L (lightness with L = 100 for lightness, and L = zero for darkness), a [(chromaticity on a green (-) to red (+)], b [(chromaticity on a blue (-) to yellow (+)], c (color saturation), h [(hue angle where 0° = red to purple, 90° = yellow, 180° = bluish to green and 270° = blue scale.

Chemical composition of snacks

As expected, the addition of sweet potato and sweet lupine flour raised the nutritional value of the product. Adding 10% sweet potato flour resulted in a significant increase in fiber, ash and total carotenoids (as shown in table 4), as a result of the high content of these elements in sweet potato flour. Also, from table 4, increasing the amount of sweet lupine resulted in a gradual increase in the values of protein, fat, fiber and ash. Values of carbohydrate and moisture decreased (as shown in table 4). These results could be explained by the high level of protein, fat, fiber and ash in sweet lupine. Our results agree with work by **Oliveira *et al.* (2015)** on rice-lupine snacks.

Table (4): Chemical composition of extruded snacks

Sample	Moisture	Protein	Fat	Fiber	Ash	Total carbohydrates	Total carotenoids	Energy (Kcal/100gm)
F1	4.55±0.19 [a]	7.54±0.16 [f]	0.25±0.08[f]	1.50±0.26 [f]	0.35±0.21 [f]	90.36±0.05[a]	1.21±0.11 [f]	393.85±0.09 [a]
F2	4.32±0.02 [b]	7.77±0.05[e]	0.29±0.03[e]	2.07±0.07[e]	0.47±0.13[e]	89.40±0.02[b]	3.47±0.09[e]	391.29±0.02 [b]
F3	4.29±0.05 [b]	8.60±0.03 [d]	0.37±0.07[d]	2.15±0.07[d]	0.57±0.08[d]	88.31±0.08[c]	3.56±0.03[d]	390.97±0.06[c]
F4	4.26±0.04[c]	9.43±0.08 [c]	0.44±0.04[c]	2.23±0.06[c]	0.67±0.03[c]	87.23±0.04[d]	3.69±0.08 [c]	390.60±0.08[d]
F5	4.23±0.03[c]	10.12±0.03[b]	0.51±0.05[b]	2.31±0.03[b]	0.81±0.02 [b]	86.25±0.04[e]	3.81±0.02 [b]	390.07±0.05[e]
F6	4.20±0.03[d]	11.10±0.02[a]	0.59±0.08[a]	2.39±0.04[a]	0.90±0.05[a]	85.02±0.04[f]	3.94±0.09 [a]	389.79±0.11 [f]

*Values are means of three replicates ±SD, on dry weight basis. ** Total carbohydrates were calculated by difference.

As shown in Table (5), addition of lupine causes an increase in iron, zinc and magnesium contents. Meanwhile calcium and phosphorus undergo slight increase. This increase may be due to the high levels of minerals in sweet lupine compared with rice flour.

Table 5: Minerals content in extruded snacks

Sample	Ca	Fe	Zn	P	Mg
F1	20.14±2.84[f]	1.67±0.84[f]	0.52±0.01 [f]	0.000±0.00[e]	0.00±0.00[e]
F2	29.48±0.15[e]	1.88±0.05[e]	1.35±0.12[e]	0.000±0.00[e]	0.00±0.00[e]
F3	29.57±0.05[d]	1.95±0.09[d]	1.43±0.05[d]	0.011±0.09[d]	3.004±0.03[d]
F4	29.63±0.03[c]	2.03±0.07[c]	1.51±0.01[c]	0.021±0.03[c]	6.128±0.01[c]
F5	29.72±0.08[b]	2.11±0.02[b]	1.57±0.07[b]	0.037±0.02[b]	9.19±0.07[b]
F6	29.78±0.07[a]	2.17±0.05[a]	1.66±0.03[a]	0.052±0.07[a]	12.26±0.05[a]

Values are means of three replicates ±SD, on dry weight basis.

Sensory Evaluation

Borba *et al.* (2005) reported that one factor that determines the acceptability of extrudate to the consumer is the texture, which should have low hardness.

The general acceptability was good at all the levels tested, with no significant differences among them. The snacks containing 7.5% sweet lupine flour was widely accepted, due to its good appearance (color) and flavor (taste and odor) than the control sample. The samples with 7.5% sweet lupine flour showed the greatest strength and least brittleness, resulting in lower hardness and greater crispness. These results agree with work by **Oliveira *et al*, 2015.**

Table 6: Sensory Evaluation of Extruded Snacks

Sample	Color	Taste	Odor	Crispness	After taste	Overall Acceptability
F1	8.69±0.15 [d]	9.55±0.07 [d]	9.63±0.03 [b]	9.33±0.08 [c]	5.57±0.14 [e]	8.51±0.12 [c]
F2	9.69±0.05 [a]	9.57±0.09 [d]	9.66±0.03 [b]	9.61±0.05 [b]	5.62±0.04 [d]	8.84±0.11 [ab]
F3	9.61±0.03 [a]	9.61±0.07 [b]	9.69±0.08 [b]	9.63±0.05 [b]	5.65±0.09 [d]	8.86±0.09 [ab]
F4	9.55±0.09 [b]	9.63±0.11 [b]	9.70±0.03 [a]	9.73±0.09 [a]	5.73±0.02 [c]	8.84±0.09 [b]
F5	9.50±0.11 [c]	9.70±0.08 [a]	9.75±0.05 [a]	9.75±0.02 [a]	6.16±0.11 [b]	8.92±0.06 [a]
F6	9.48±0.07 [c]	9.45±0.02 [d]	9.49±0.09 [c]	9.35±0.08 [c]	6.32±0.05 [a]	8.71±0.02 [c]

Values are means of three replicates ±SD, on dry weight basis.

Recommended dietary allowance (RDA)

The percentages of the recommended dietary allowances (% RDA) are provided from 100g of snacks for children are showed in table -7-. As expected, the addition of sweet potato and lupine flour raised the nutritional value of the product.

Table 7: Percentages of the recommended dietary allowances (% RDA) for children 9-12 years

	Males							Female						
	Protein (34 g/d)	Fiber (31 g/d)	Carbohydrate (130 g/d)	Ca (1300 mg/d)	Fe (8 mg/d)	Zn (8 mg/d)	Vit A (600µg /d)	Protein (34 g/d)	Fiber (26 g/d)	Carbohydrate (130 g/d)	Ca (1300 mg/d)	Fe (8 mg/d)	Zn (8 mg/d)	Vit A (600µg /d)
F1	**22.18**	**4.84**	**69.30**	**1.55**	**20.87**	**6.50**	**16.81**	**22.18**	**5.77**	**69.30**	**1.55**	**20.87**	**6.50**	**16.81**
F2	**22.85**	**6.68**	**68.77**	**2.26**	**23.50**	**16.87**	**48.19**	**22.85**	**7.96**	**68.77**	**2.26**	**23.50**	**16.87**	**48.19**
F3	**25.29**	**6.94**	**67.93**	**2.27**	**24.38**	**17.87**	**49.44**	**25.29**	**8.27**	**67.93**	**2.27**	**24.38**	**17.87**	**49.44**
F4	**27.47**	**7.19**	**67.10**	**2.27**	**25.13**	**18.87**	**51.25**	**27.47**	**8.57**	**67.10**	**2.27**	**25.13**	**18.87**	**51.25**
F5	**29.76**	**7.45**	**66.35**	**2.28**	**26.38**	**19.63**	**52.92**	**29.76**	**8.88**	**66.35**	**2.28**	**26.38**	**19.63**	**52.92**
F6	**32.65**	**7.71**	**65.40**	**2.29**	**27.13**	**20.75**	**54.72**	**32.65**	**9.19**	**65.40**	**2.29**	**27.13**	**20.75**	**54.72**

(Food and Nutrition Board, Institute of Medicine, & National Academies, 2004)
1 µg retinol=12 µg carotene = 1 µg of retinol activity). Vitamin A dietary reference intakes (µg RAE/day):

It could be noticed that consuming fortified snacks could provide children with part of their daily requirements of protein, dietary fiber, carbohydrate, calcium, iron and zinc.

Conclusion

The product of the mixture prepared from extruding broken rice, sweet potato flour and sweet lupine flour had an increased nutritional value. There were decreases in the EI, WAI and WSI values as the concentration of lupine increased. The extruded flours showed increased brightness as the concentration of lupine increased in the extruded mixtures due to a reduction in the starch content, and consequently, the minimization of browning reactions, such as caramelization and Maillard reactions. However, samples produced with lower amounts of lupine, and consequently, higher starch contents showed a more reddish color.

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