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OPTIMIZATION OF THE FORMULATION CONDITIONS FOR DEVELOPMENT OF EXTRUDED READY-TO-EAT SNACKS USING GERMINATED MUNG BEAN AND CORN

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ABSTRACT

These days, health benefits and physiological effects of leguminous seeds have been highlighted. Mung bean contains high levels of necessary amino acids, polyphenols and oligosaccharides caused it to be a favorite nutritional food. Sprouting is an important process in order to increase the biologic activity and secondary metabolites such as phenolic acids and flavenoids. Sprouts are rich in minerals and vitamins. Expanded products with corn/germinated mung bean flour was prepared using a twin-screw extruder which temperature was set at 145 ˚C and screw speed was 160 rpm and the varying parameters were total moisture (13-19 %)and germinated mung bean flour content (10-30 %). Measured properties were bulk density, expansion index, hardness, Water absorption and solubility indexes ,oil absorption index (OAI), Crude protein (CP), Digestible crude protein (DCP), DPPH˙ (1, 1- diphenyl-2-picryhydrazyl), total phenol content ,Water activity and moisture content and color parameters (L, a and b) of the extrudates based on response surface methodology. Results showed that as feed moisture content increased, density, hardness, WAI, crude protein, L and b increased and addition of germinated mung bean flour to formulation caused an increase in density, hardness, crude protein, L and a. The sample that contained 13% feed moisture and the feed ratio was 10% showed the best antioxidant activity. The optimized extrusion condition for produced sprouted mung bean extrudate was at middle feed moisture (16%) and less than 20% germinated mung bean flour content. So, the well expansion properties, low product density and favorite hardness of extruded snack were obtained.

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Introduction

Extrusion cooking is vitial and popular food processing technique classified as a utilizes high temperature with short time process to produce various snacks. In recent years, there is an increasing demand for enriched product with bean germinated such as mung bean. Mung bean is an important source of easily digestible high quality protein for vegetarians and sick persons. In addition to this, mung bean germinated source of dietary proteins, carbohydrates, minerals, vitamins, natural source of antioxidants and etc. In this process, product quality can vary depending on the extruder type, feed moisture, screw configuration and temperature profile in the barrel, screw speed and feed rate. This study can be used to help implement strategies designed to enhance the product's extrudates.

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Legumes are rich sources of proteins, especially some essential amino acids such as lysine, so can play an important role in a healthy diet and may reduce the consumption of animal food sources against vegetable sources (1; 2) Cereal proteins are poor sources of lysine, so legume and cereal proteins are nutritionally complementary (3). Mung bean (*Vigna radiata*) is the most important legume due to its high proteins and carbohydrates. Its protein quality is similar to or better than other legumes such as chickpea, black gram, peas, pigeon pea, etc. Mung bean is rich in essential amino acids, including leucine, isoleucine and valine, which can be combined with other plant sources (like whole grains or some vegetables) to make a "complete protein."(4, 5). Mung beans are a high source of nutrients including: manganese, potassium, magnesium, folate, copper, zinc and various B vitamins (6). High levels of proteins (20-33%), amino acids, oligosaccharides, dietary fibers and significant amounts of bioactive phytochemicals. Polyphenols in mung beans are thought to be the main contributors to the antioxidant, antimicrobial, anti-inflammatory and anti-tumor activities of this food and are involved in the regulation of lipid metabolism (7; 8)

Biological utilization of pulses is limited due to deficient sulphur containing amino acids and the presence of antinutrients including phytic acid, saponins, polyphenols, enzyme inhibitors, lectins, etc (9).

Germination is an inexpensive and simple method to improve nutritive value of legumes and several studies have confirmed that nutrients may increase and anti-nutrients may decrease in germinated food grains compared to the un-germinated ones and so germinated legumes considered as functional foods (10). Several nutritive factors such as vitamin concentrations and bioavailability of trace elements and minerals are reported to increase during germination. At the same time there are indications that germination is effective in reducing phytic acid and flatulence causing oligosaccharides stachyose and raffinose, increasing protein digestibility and improving sensory properties (11)

Extrusion is a continuous cooking and shaping process and also versatile, low cost and efficient method for the production of expanded snacks (12; 3). These products are usually low in bulk density and are often sold as high-fiber, low-calorie, high-protein and nutritional product but it should be mentioned that all of extrudates don't have these good properties (13; 3). This process of high temperature short time extrusion causes starch gelatinization, protein denaturation, lipid modification and also inactivation of enzymes, microbes and many antinutritional factors (14; 15).

Snack foods have become a significant part of the daily diet of many peoples, especially children, and so may effect on overall nutrition (16). The various sensory properties regards to snack foods are appearance, texture, taste, colour and flavor which texture is the most important one (17; 18). Thesedays nutritive value enhancement of daily snacks is one of the most important subjects in food researches. There are several perusal investigating the effect of extrusion conditions on structural and textural characteristics of starch-based snack [19; 20; 21; 22; 23). The extrusion behavior of protein-starch systems has been reported by many researchers, but there is still a lack of knowledge of extrudate properties using legume and legume-cereal blends (24) There is an increasing consumer demand for more nutritious snacks rich in protein and many other nutrients (25; 23).

The aim of this study was to investigate the effect of extrusion cooking conditions on the physicochemical, nutritional and functional characteristics of extruded corn-germinated mung bean mixtures. Physical characteristics such as expansion, density, and hardness are important parameters to evaluate the consumer acceptability of the final product, furthermore total phenol and antioxidant contents, color parameters and functional properties are the other factors that affect the snacks acceptance by consumers.

1. Materials and methods

1.1. Raw materials

Mung bean (*Vigna radiata*) seeds were provided from Mashhad, Iran and stored at 4°C. Seeds were soaked in distilled water with ratio of 1:5 w/v at a controlled temperature for 48 h. The water was eliminated and the seeds were incubated at 35°C for 3 days (Yasmin et al. 2008). During incubation seeds were covered with moisture linen cloths and water was sprayed once a day to maintain the moisture. The seeds were analyzed for moisture, fat, ash, protein and fiber contents before use.

1.2. Sample preparation

After incubation process, the sprouts were dried in an air oven at 40 ˚C for 12-16 h. The dried material was coarsely ground and passed on sieve with mesh size of 30.Corn and SMBF were mixed to the desired ratios: 10, 20 and 30% legume/corn flours. The feed moisture content levels were 13%, 16% and 19% wb. Feed mixtures were adjusted to the desired moisture content by spraying calculated amounts of distilled water and mixing thoroughly for 15 min. Samples were packed in polyethylene bags and kept in the refrigerator overnight to equilibrate the moisture. corn/germinated mung bean flour (SMBF) contain about 31.93 % protein, 1% fat, 5% cure fiber, 3.98 % ash, 117.3 mg Fe, 53 mg Zn and 0.5 mg P.

1.3. Extrusion cooking

A co-rotating twin screw extruder (Jinan Saxin, model DS56, China) was used. The screw's geometry was: length of80 cm, diameter of 8 mm, maximum rotation speed of360 rpm and die diameter of 3 mm. The material was fed into the extruder using a volumetric feeder. The temperature during extrusion was adjusted by varying the temperature in the barrel, screw and die using electric heaters. Steady-state conditions were reached after 10 min and then samples were collected, put on the 40°C oven for 2 h and stored in appropriate laminated bags for further analysis.

1.4. Experimental design

Response surface methodology (RSM) was used to investigate the effect of two independent variables(feed moisture and sprouted mung bean to corn flours ratio) onthe15 response variables which consist of functional properties (water absorption index, water solubility index, oil absorption index), macro and micro structure (bulk density and expansion index), hardness, crude protein content, digestible crude protein content, DPPH˙ (1, 1- diphenyl-2-picryhydrazyl), total phenol content, water activity, moisture content and color parameters (L, a and b). RSM enables the evaluation of the effects of many factors and their interactions on response variables. The main advantage of RSM is the reduced number of experimental trials required to evaluate multiple parameters and their interactions [43]. In the present work, the experiments which performed according to a central composite face-centered design. Variables' levels are given in Table 1.

Table 1. Levels of variables for the experimental design

Independent variables		**Levels**		
	Coded	-1	0	+1
Feed moisture (%)	X_1	13	16	19
Legume/corn ratio	X_2	10	20	30

1.5. Analysis

1.5.1. Expansion Index

The radial expansion of the selected extrudates at different portions was measured using vernier calipers and an average of ten measurements was recorded. The expansion ratio was calculated as the following formula (Rweyemamu et al, 2015)

Expansion ratio (ER)=$\frac{D_e^2}{D_d^2}$

Where: D_e= Diameter of extrudate; D_d= Diameter of die

1.5.2. Bulk density

The extruded rods have a visible porous surface (small air gaps). Therefore, the glass bead volume displacement method was used to evaluate the bulk density (BD) of the extrudates (26). The glass jar was filled with beads and the surface was scraped with a spatula to remove excess beads. The weight of beads required was determined using atop loading balance with 0.01g accuracy and the volume of beads was measured using a 500mL graduated cylinder. Subsequently, 5 g of the extruded samples were cut into short segments of about 1.5 cm for density determination. Glass beads were added to the glass jar to form a thin layer of approximately 1 cm at the bottom. The beads were poured in until all the pieces were covered. This procedure was repeated to include all the remaining pieces of extrudates. Then, enough beads were poured to fill the glass jar. The weight of the measuring glass jar along with the beads and extrudate pieces were recorded. The difference in weight between the glass jar filled with beads plus extrudate and the glass jar filled with only beads was used to determine the volume displaced by the extrudate pieces. The bulk density was expressed as the ratio of the weight of pieces to their volume in g/cc (27).

1.5.3. Water absorption and solubility indexes

The water absorption index (WAI) was determined according to the method of Anderson et al (28): in which distilled water (5 mL) was added to ground sample (0.2 g) in a weighed15 mL glass centrifuge tube. The tube was agitated on a Vortex mixer for 2 min and then centrifuged for 20 min at 700g. The supernatant liquid was poured into a tarred evaporating dish. The remaining gel was weighed and the WAI was calculated as:

$$\text{WAI} = \frac{m_g}{m_s}$$

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:

$$\text{WSI} = \frac{m_{ds}}{m_s} \cdot 100$$

Where m_{ds} is the weight of dry solids from the supernatant (g) and m_s is the weight of the sample (g) (3).

1.5.4. Oil absorption index

Oil absorption index (OAI) was determined according to the method of Liadakis et al (29): refined corn oil (3 mL) was added to the sample (0.5 g) in a graduated 15 mL glass centrifuge tube. The tube was agitated on a Vortex mixer for 1 min, and then left for 30 min and centrifuged for 20 min at 700g; the volume of the free oil was read. OAI was calculated as:

$$\text{OAI} = \frac{V_{oil}}{m\ _s}$$

Where V_{oil} = the volume of oil absorbed (mL) and m_s = the weight of the sample (g) (Lazou[b] et al. 2010)

The results presented are the mean values of three replications.

1.5.5. Water activity and moisture content

Water activity (aw) of the snack bar was measured separately at room temperature using a water activity meter (Lab Master aw, Switzerland). Moisture content was determined using a 105°C oven and the heating process continued until it reached the equilibrium sample weight.

1.5.6. Chemical analysis

Ash, protein and fat analysis of raw materials was carried out using standard procedures of AOAC (30). All analyses are expressed as the mean (±SD) of triplicate analysis.

1.5.7. Color

Hunter Lab Lab Scan II (Hunter Associates Laboratory, Inc., Reston, VA, USA) was used to determine color values of the raw materials and ground extruded in terms of the Hunter L, a and b. The L value represents the lightness/darkness of the sample and ranges between 0 for black to 100 for white sample. The a and b values represent redness/greenness and yellowness/ blueness of sample. The measuring head was equipped with 51 mm diameter viewing port and used the system of diffuse illumination with 10 viewing geometry. D65 (day light condition) was chosen as the measurement light source. A white tile was use to calibrated the instrument. The extrudates were ground in a laboratory grinder and passed through a 60 mesh sieve prior to color analysis. For each sample, three measurements were taken and averaged (31; 32).

Total phenol content

The total phenolic content was determined using the Folin–Ciocalteau method (33) as modified by Gao et al (34).Based on Singleton and Rossi (33) reports, for total phenol content determination, 100 mg of finely ground sample was extracted in 2.5 mL of acetone/water (80:20, v/v) (Fisher, Ottawa, ON, Canada) for 2 h in a rotary shaker. After this period, the samples were centrifuged at 3000g in a table centrifuge (GLC-1, Sorval, Newton, CT, USA) for10 min. Thereafter the supernatant was transferred to a 3 ml syringe (Fisher) and filtered through a 0.45 lm sterile Hydrophilic polyvinylidene fluoride (PVDF) filter unit (Fisher). The filtrate was collected for further analysis. An aliquot (0.2 mL) of extract was added to 1.5 mL of freshly diluted 10-fold Folin–Ciocalteau reagent (BDH, Toronto, ON, Canada). The mixture was allowed to sit for 5 min and then 1.5 mL of sodium carbonate solution (60 g/L) (Sigma, St. Louis, MO, USA) was added. Afterwards, the mixture was incubated for 90 min and the absorbance read at 725 nm. Acetone/water (80:20, v/v) was used as a blank and ferulic acid (Sigma) was used as the standard. The results were expressed in mg of ferulic acid equivalents per 100 g of sample. Linearity range of the calibration curve was 20–200 μg (r = 0.99).

1.5.8. Antioxidant activity

Antioxidant activity was measured using a modified version of Chen and Ho (1995). For this assay, 200 μL of extract was reacted with 3.8 mL of 2,2-diphenyl-1-picrylhydrazyl (DPPH) (Fisher) solution (6.34x10^{-5} M in methanol). The decreasing absorbance was monitored at 517 nm (Ultraspec 200, Pharmacia Biotech Piscataway, NJ) in the dark at 30 min against a methanol blank. The control consisted of 200 μL of acetone/water (80:20, v/v) in 3.8 mL of DPPH solution. The results were obtained as a percent of discolouration according with below formula:

$$\left[1-\left(\frac{\text{Absorbance sample}}{\text{Absorbance control}}\right)\right]\times 100$$

Simultaneously to the samples, 6-hydroxy-2, 5, 7, 8-tetramethylchroman-2-carboxylic acid (Trolox) (Sigma) was used as a standard and the results were expressed as μ mol of Trolox equivalents per 100 g of sample. The linear range of the calibration curve was 2.5 to 20 μ mol (r = 0.99).

1.5.9. Hardness

This test was done at room temperature (25°C) using a AMETEK Lloyd Texture Analyzer (TA-Plus instruments Ltd, USA). Hardness in N was determined by measuring the maximum force required to break the extruded samples using three point bend test with a sharp bladed probe (55 mm wide, 40 mm high, 2 mm thick). Speed in this test was 2 mm/s and the penetration depth was 8 mm (35).

2. Results and discussion

2.1. Effect of formulation variables on physical properties of extrudates

Product density and expansion ratio are closely related and describing the degree of puffing in extrudates (36; 23).The bulk density of the extrudates varied between 0.048 and 0.126 g/cm^3. The extrudate density was found to be most dependent on feed moisture. As shown in figure 1, increased feed moisture caused to a sharp increase of extrudate density value and on the other hand, by increasing the SMBF content, extrudate density tends to increase in most of the route. Low density is a desirable characteristic of expanded products was obtained at low feed moisture and moderate concentration of SMBF (23). The bulk density of extrudate explains the degree of expansion undergone by the melt as it exits the extruder (15). The R^2 and Adjusted R^2 values of the model are 0.8748 and 0.8488, respectively. The F-value for bulk density was significant ($P<0.05$).

Expansion ratio is a measurement of expansion in diameter of extrudate. The expansion ratio of extrudates was between 3.33 and 6.63. An inverse relationship between expansion ratio and density of extrudates has been earlier reported (37). chaiyakul et al (2009) as observed in this study (Fig. 1 and 2). The product expansion ratio decreased with increase in feed moisture and SMBF concentration. The regression analysis results showed non-significant ($P>0.05$) effect of feed moisture content whereas there was a significant ($P<0.05$) effect of SMBF concentration on expansion of extrudates. It was understood from the response surface plot (Fig. 2) that extrudates showed a high in expansion ratio at low level of feed moisture content. The R^2 and Adjusted R^2 values of the model are 0.9497 and 0.9190, respectively. This was in agreement with the study of Ding et al. (38), Ding et al. (21), Lazou et al. (24) and Keawpeng et al. (15).

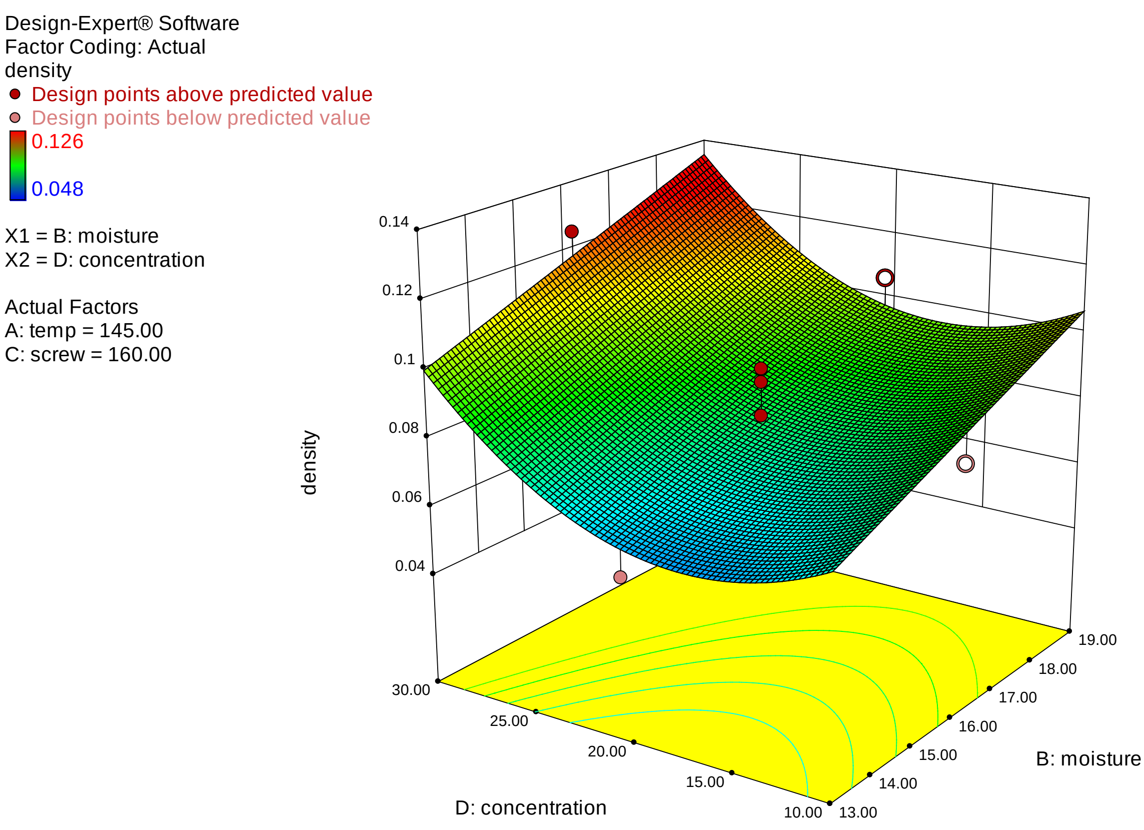

Fig.1 Effect of feed moisture and SMBF addition on product density.

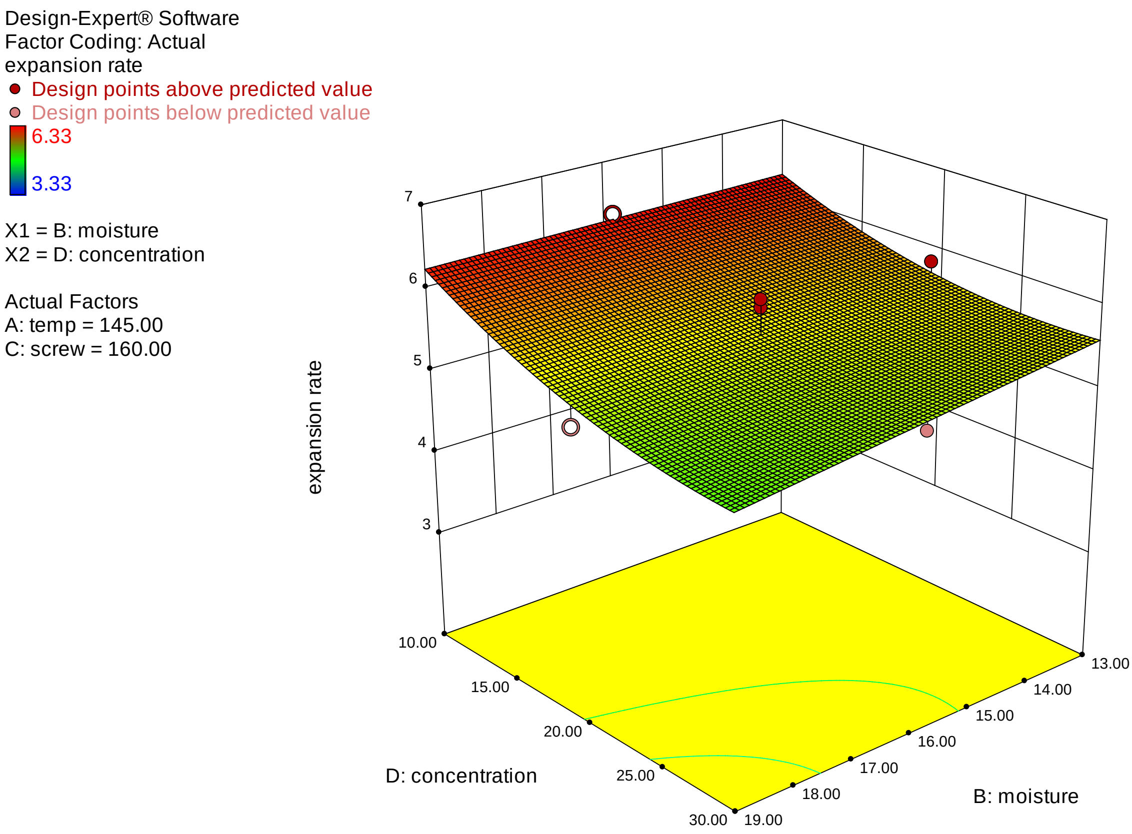

Fig.2 Effect of feed moisture and SMBF addition on product expansion rate.

As moisture content increases the possibility of starch gelatinization may decreases. This phenomen a caused lower expansion (39).

The high dependence of bulk density and expansion ratio on feed moisture would reflect its influence on elasticity characteristics of extrudates. High levels of feed moisture during extrusion may reduce the dough elasticity and reduced gelatinization of starch content and therefore decreasing the expansion ratio and increasing the density of extrudate (21).

Increasing levels of SMBF resulted in a significant decrease in expansion ratio. By decreasing the amount of corn starch in the mixtures due to increasing level of protein and fibre through addition of SMBF, less expanded products were produced due to interactions between these components and the starch. This lower expansion can also be explained on the basis that fibre can rupture cell walls and prevent air bubbles from expanding to their maximum potential (40).Our finding is in accordance with Anton et al (31) that fortified corn starch-based extruded snacks with common bean.

Unique structure and crispy texture of extruded products are important for their acceptability by consumers (24). Evaluation of hardness is very essential parameter because excessive hardness is not a desirable feature for expanded snacks. The effect of feed moisture and SMBF concentration on hardness of extrudate is shown in Figure 3. All two factors had significant effect on extrudate hardness ($P<0.05$).The R^2 and Adjusted R^2 values of the model are0.8985 and 0.8528, respectively. An increase in feed moisture up to 16% has no influence on hardness of extrudates, however in higher levels of humidity, increase in SMBF concentration led to a gentle increase of hardness. The hardness of extrudates ranged from 1.05 to 14.8 N. Low hardness, which is a favored property of extrudates was observed at low feed moisture and low level of SMBF. Our finding is similar to previous studies reported that the hardness of extrudates increased as the feed moisture content increased (38; 41; 23). Possible cause of decrease in hardness related to higher levels of feed moisture which caused expansion to reduce. Moisture content of cereal foods is the most reason changes of textural characteristics (42; 13; 43). In addition to this, reduction of hardness due to low density products naturally. It also approve with the work of Areas (1992) and Anton et al. (31) which mentioned that moreover of protein to starch-rich flours produces the extrudates that are less expanded and more harder. Increasing of perencentage of protein cause to developing fibre that it increases the hardness of the final products as a consequence of its effectuate cell wall thickness(44). In addition to this, feed moisture content impressionable the cellular structure of snack in same way as percentage of mung flour(24).

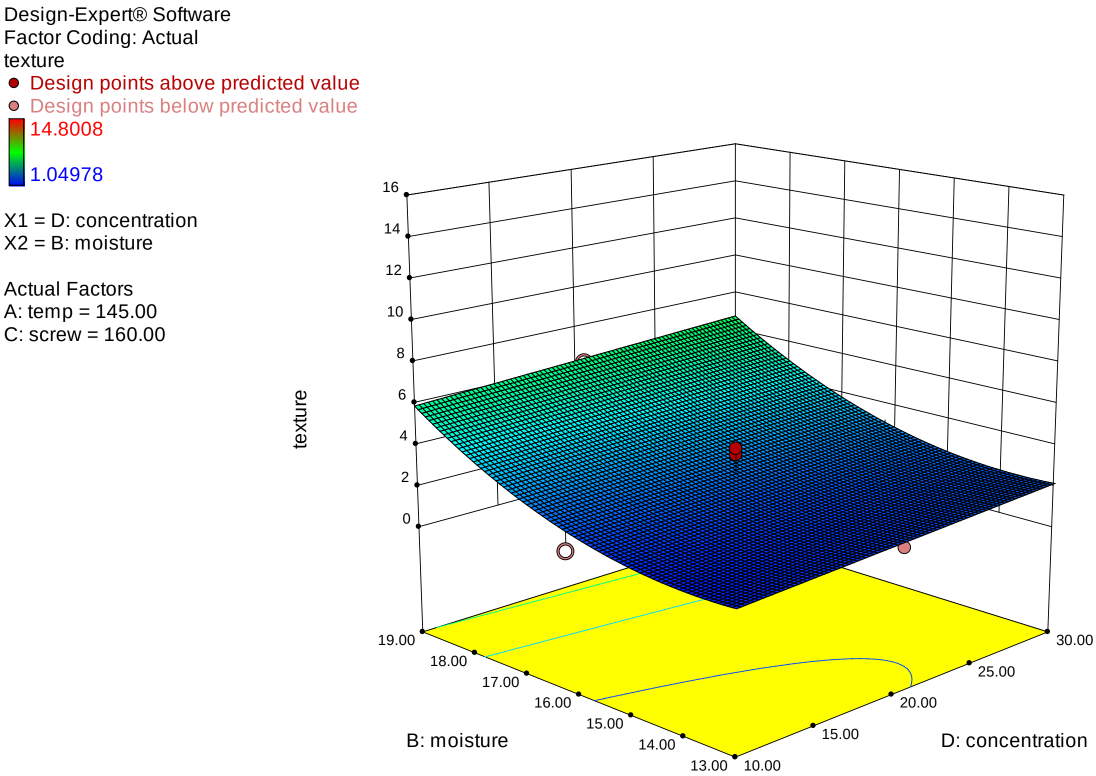

Fig.3 Effect of feed moisture and SMBF addition on product hardness.

2.2. Functional properties

The moisture content of extrudates in our study was in the range of 1.27 to 3.85(g/100 g wb). Water is a component of food that influences food stability, quality and physical properties. A high water content can cause plasticizing or antiplasticizing effects and cause brittle material to lose crispness consequently (45).

Water activity (aw) measurement helps predict food mechanical characteristics, stability and shelf life. A low aw value would offer a good shelf life and preserve product quality during storage. So aw can affects microbial spoilage as well as chemical reactivity and enzymatic activity (46). The changes in water activity are responsible for the mechanical properties of snack bars, which are probably associated with differences in the product's micro-structure and chemical composition (42). The aw values of extrudates varied between 0.011 and 0.1797. These aw values are all below 0.7, indicating low risk of microbial spoilage and pathogenic damage and good shelf life (47; 42).

Water absorption and water solubility indexes can be used to estimate the functional properties of snack foods. The WAI measures the volume occupied by the granule or starch polymer after swelling in excess water (48; 41). While the WSI determines the amount of free polysaccharide or polysaccharide released from the granule after the addition of excess water (41). In other words, WAI is used as a source of quality attributes of extruded products and is considered as an indicator of starch gelatinization. Also, WSI can be defined as an indicator for the decomposition of molecular compounds and quantifies the degree of starch conversion during extrusion process (49)

The WAI of extrudates ranged from 1.4575to 10.554 g/g dry sample. The model F-value is significant ($P< 0.05$).The R^2 and Adjusted R^2 values of the model are 0.9126 and 0.8733, respectively. WAI depends on two factors; first the availability of hydrophilic groups to bind water molecules and second the gel forming capacity of macromolecules (50). Increasing feed moisture significantly increase the WAI of extrudates (Fig. 4). Similar effects have been reported earlier for other kinds of extrudates (51; 52). Decrease in dough viscosity would be affected by moisture content increase, so the extensive internal mixing and uniform heating process may enhance starch gelatinization and consequently water absorption increase (51).By incorporating SMBF in snack formulation, protein content of extrudates increases. Legume proteins have hydrophilic groups therefore by increase of legume content in extrudates, WAI increase.

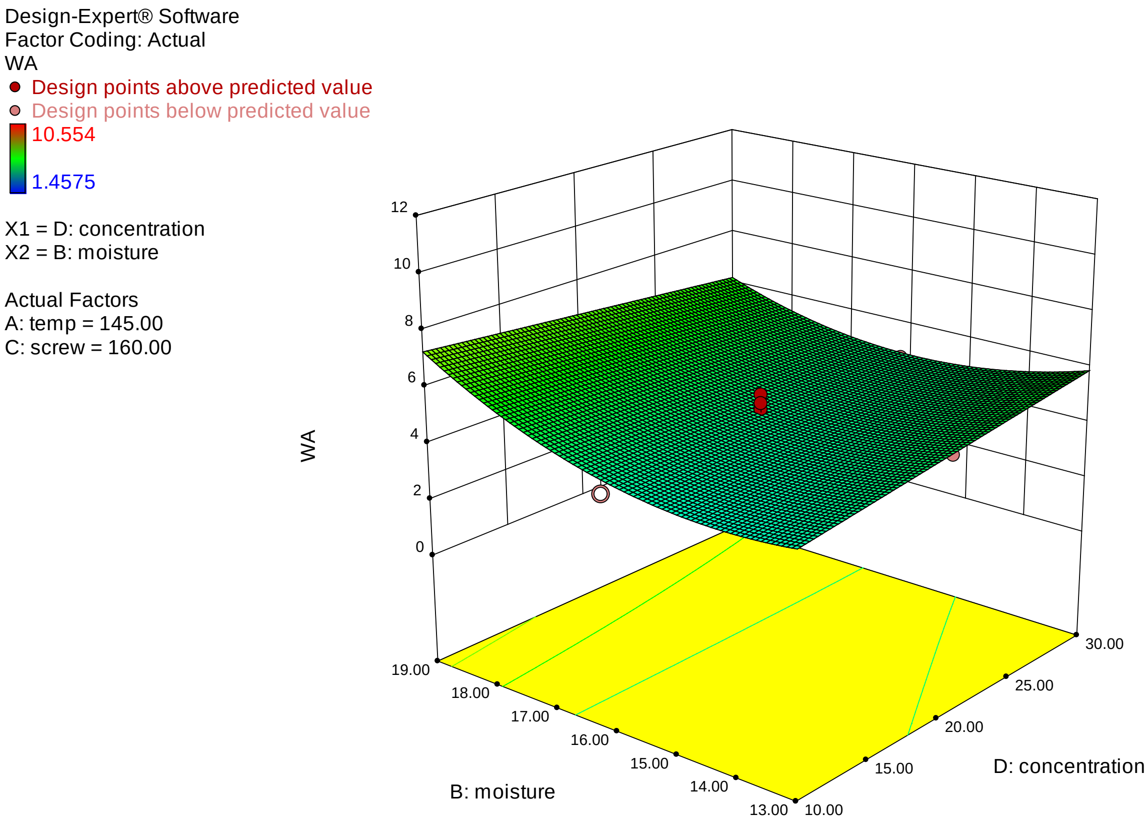

Fig.4 Effect of feed moisture and SMBF additionon product WAI.

The WSI of extrudate ranged between 20.8 and 71.65% (db). The model's F-value of 47.43 indicates that the model is significant ($P < 0.05$). The R^2 and Adjusted R^2 values of the model are 0.9552 and 0.9351, respectively. Increase of feed moisture caused WSI to decrease (Fig. 5). Ding et al. (38) and Stojceska et al. (39) also reported similar findings.

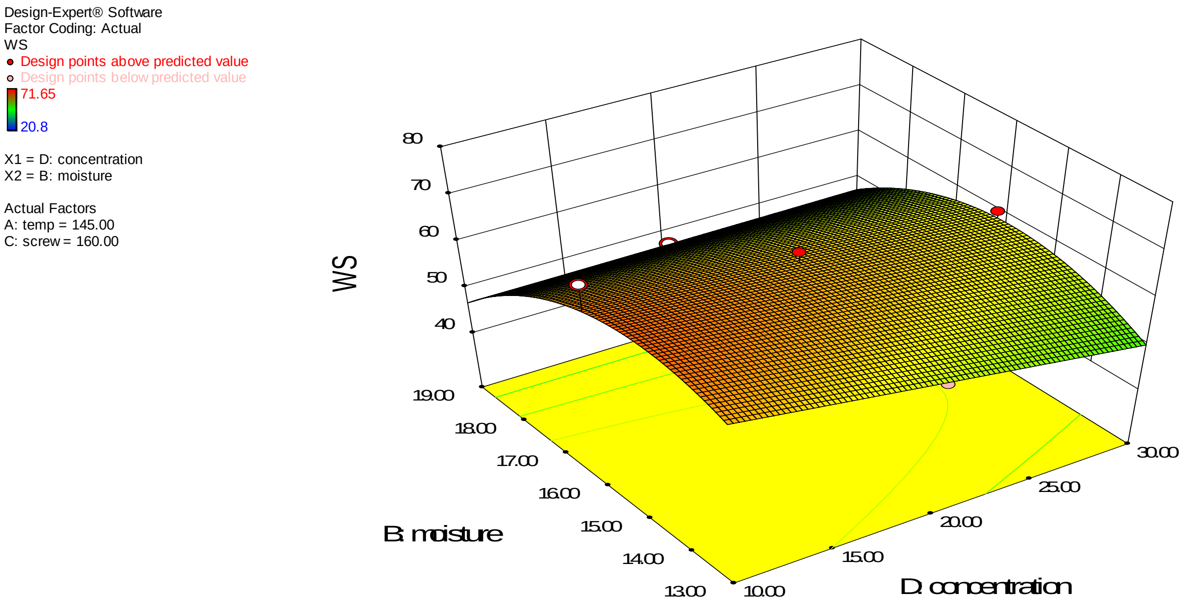

Fig5. Effect of feed moisture and SMBF addition on product WSI.

Dextrinization is the principal mechanism of starch degradation during low moisture extrusion process (50). Therefore, the reducing trend of WSI by feed moisture content is in agreement with previous reports (53; 54). The increase of material ratio (SMBF proportion) increased protein content of extrudates. Extrusion cooking led to loss in protein solubility due to denaturation process and so some structural changes may occur that enable hydrophilic groups such as –OH, –NH2, –COOH and –SH to form cross links with starch (20). So, the incorporation of proteins in extrudates was expectedto decrease WSI (3).

WSI and WAI are two important parameters of the physicochemical changes which represent the hydrophilic / hydrophobic character of the ingredient components, and principally relate to the degree of starch fragmentation caused by extrusion cooking. A higher WSI means the presence of solutes from the gelatinization, and are sometimes related to dextrinization of starch, while a higher WAI shows the existence of huge starch fragments due to minor starch degradation. These effects could also result from protein denaturation and the hydration and swelling dynamics of fibers (55).

OAI ranged from 2.6 to 5.58 ml/g. The model's F-value of 16.13 indicates significant influence ($P < 0.05$).The R^2 value of the model is 0.8599. Generally, the OAI can be used as an indicator of the hydrophobic nature of extrudates.

OAI decreased with increasing feed moisture content (Fig. 6). Our results are in agreement with the findings for rice and bean extrudates (53; 56). The rise of feed moisture content decreases the temperature of melted material, and the OAI of extrudates becomes lower because there would be small amounts of molecules, which favor OAI. The increase in SMBF/corn ratio decreased the OAI of extrudates. Lazou and Krokida (2010) reported that corn extudates showed the highest values for OAI and the presence of proteins in the extrudates lowered the OAI. This matter has been reported in bean extrudates (53) and is in agreement with our results. Kinsella (57) explained the mechanism of fat absorption as a physical blockade of oil, wherease several authors associated oil absorption capacity to the non-polar side chains of proteins (Bencini 1986; 58; 59). Different protein concentrations, amounts of non-polar amino acids, different conformational features and starch-protein-lipid binding could be the reasons for different oil retaining characteristics (60).

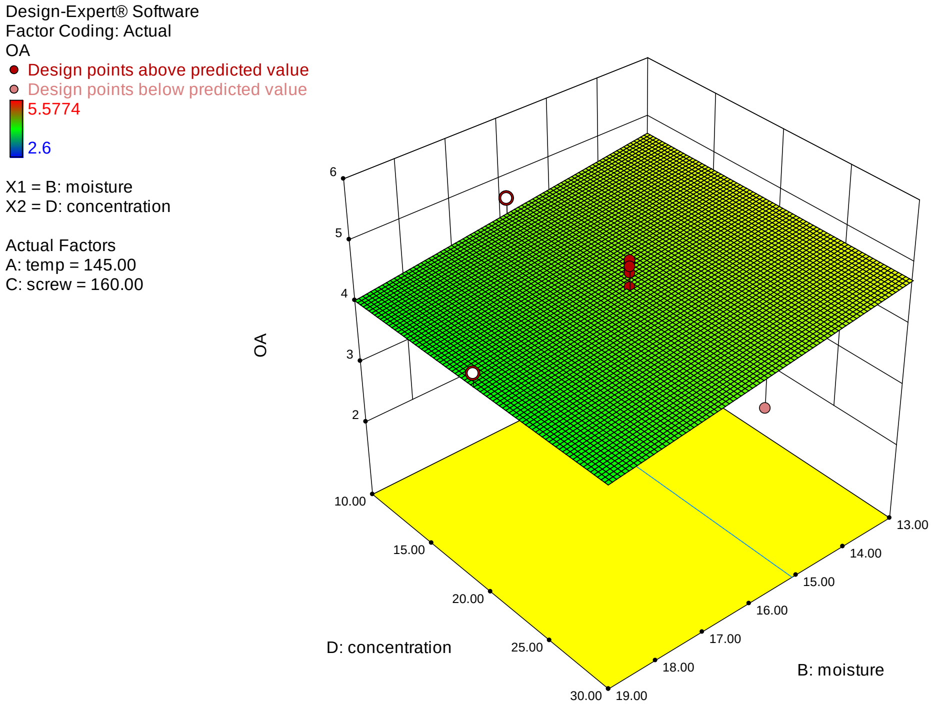

Fig6. Effect of feed moisture and SMBF addition on product OAI.

The regression analysis results showed significant ($P<0.05$) effect of feed moisture content and non-significant ($P>0.05$) effect of SMBF concentration on OAI of extrudates.

2.3. Color parameters

Food color plays an important role in quality evaluation directly related to the acceptability of food products, and is an important physical property to assess extrudate products. As indicated in ANOVA table, quadratic model for L, a ad b color parameter was found to be significant ($P>0.05$) . R^2 for L, a and b color parameters were 0.8541, 0.8620 and 0.9454 respectively. The extrudates had color values of the ranges: L: 59.76–68.8; a: 0.63–4.73; b: 23.47–27.3.

As feed moisture increased, lightness (L) and yellowness (b) increased but redness (a) decreased (Fig. 7, 8 and 9). These phenomena may be related to good dispersion of material due to high feed moisture content. On the other hand, increase in material ratio led to increase in b and decrease in L and b. These trends in color parameters of extrudates containing SMBF may be related to variation in composition of feed mixture that contained of material with different colors (61).

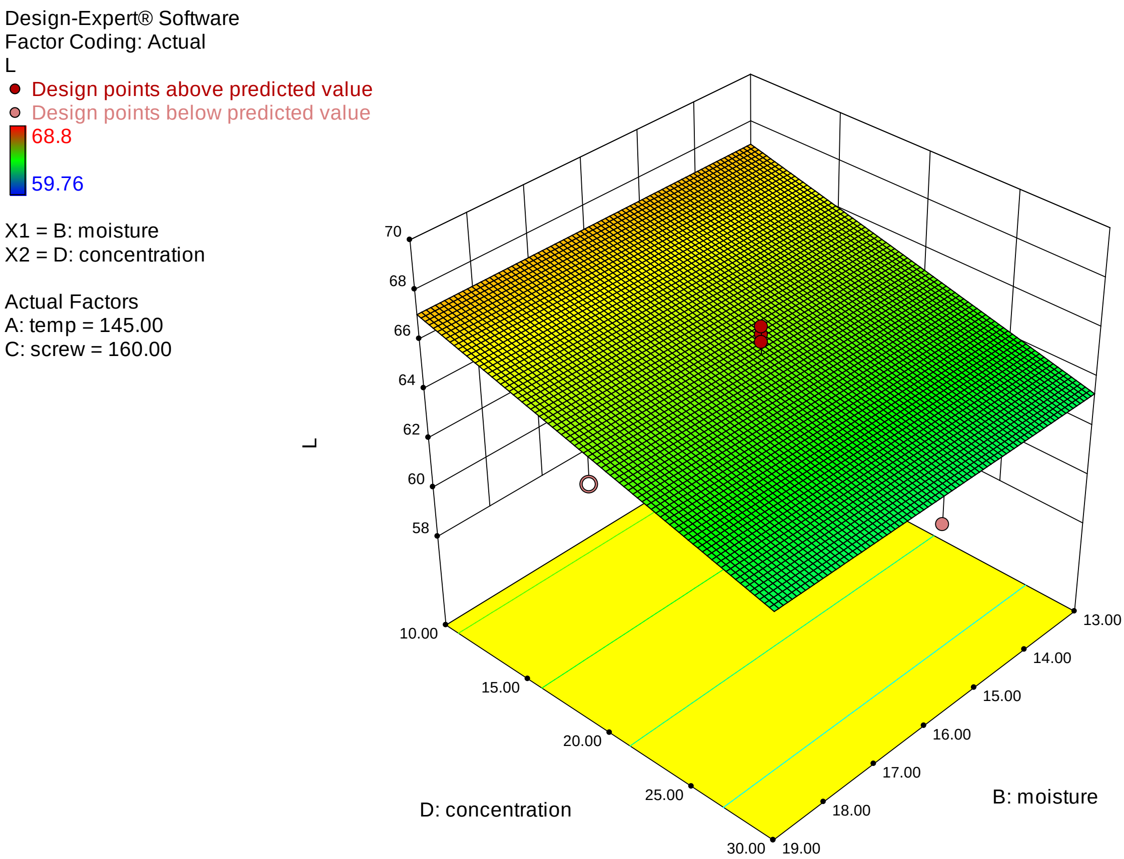

Fig7. Effect of feed moisture and SMBF addition on product L value.

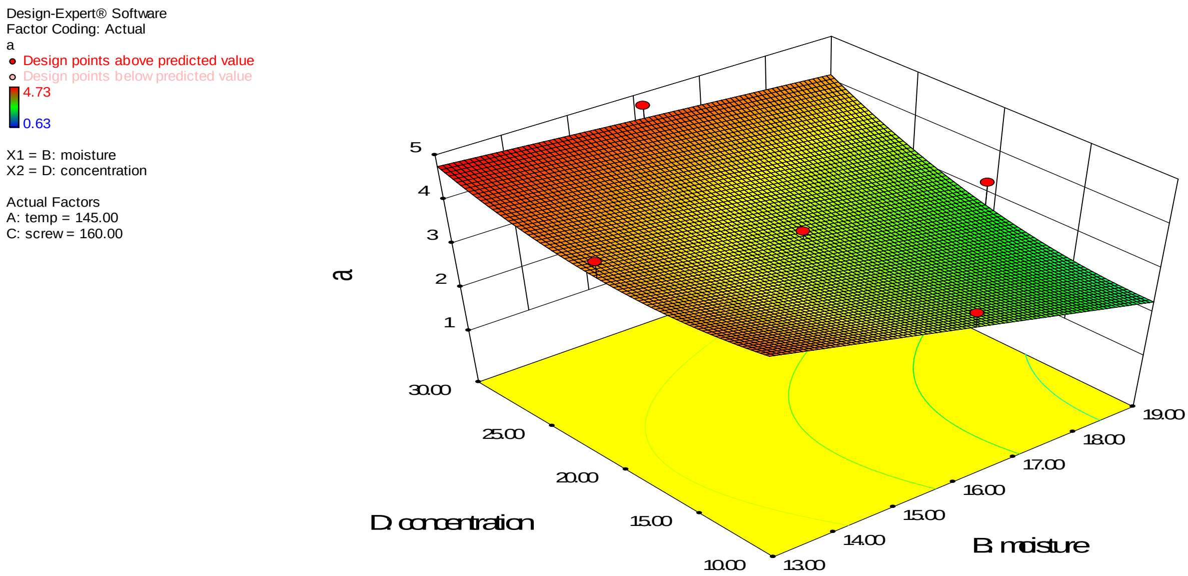

Fig8. Effect of feed moisture and SMBF additionon product a value.

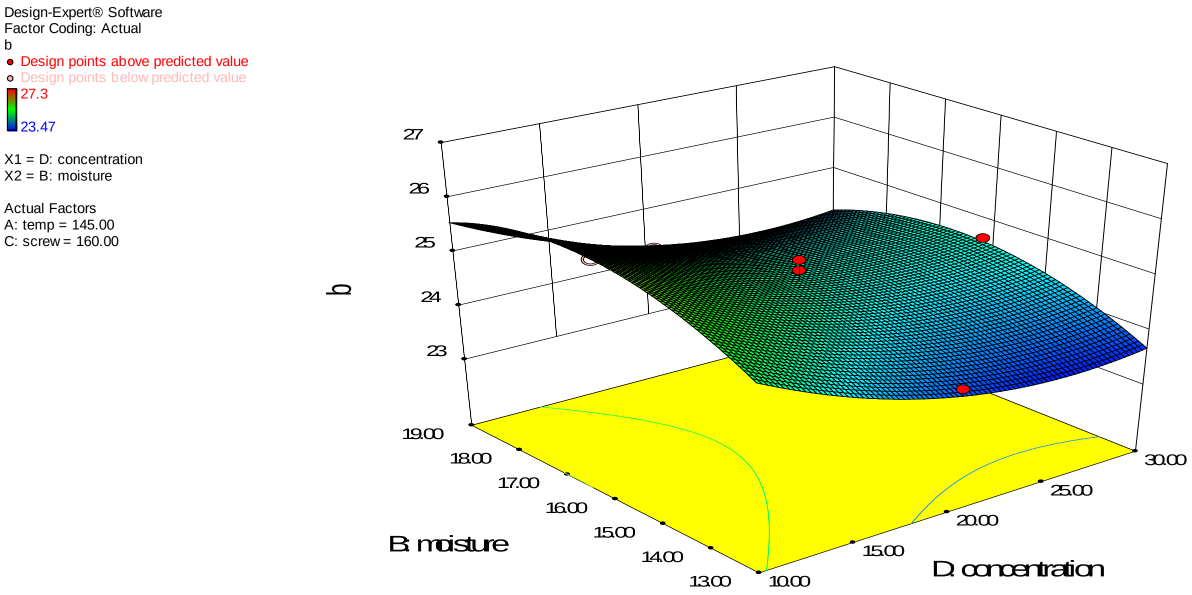

Fig9. Effect of feed moisture and SMBF additionon product b value.

2.4. Antioxidant activity

Polyphenols are plant secondary metabolites, which are able to reduce reactive oxygen species (ROS) by donating hydrogen atoms of phenolichydroxyls and by transferring electrons from suchphenolic hydroxyls or phenoxide anions (62). Polyphenolicshave been specified as good antioxidants and have an important effect in sensory quality such as color, taste and flavor of foods (63; 64).

Sample which was comprised of 30% SMBF and 19% moisture content had the lowest total phenol content of 0.34 mg/g. On the other hand, the highest total phenol content of 0.76 mg/g that contained 13% feed moisture and the feed ratio was 30%.

DPPH˙ is the symbol of antioxidant activities of pulses. DPPH radical is an oil-soluble free radical that becomes stable by accepting an electron or hydrogen from an antioxidant (65).

The lowest DPPH of 0.148 was found in sample containing 13% feed moisture and 20% feed ratio. This trend is consistent with the total phenolic content results discussed above. Anton et al. (31) also mentioned the same results as our study. In return the highest DPPH (0.445) radical scavenging activity was observed in sample that contained 13% feed moisture and the feed ratio was 30%.

In this study, the total phenolic compounds and total antioxidant capacity of the samples were investigated. It was found that neither feed moisture content nor adding ratio of SMBF to the formulation have any significant effect on the DPPH of the samples. It was found that neither adding ratio of SMBF to the formulation have significant effect on the phenol content of the samples Ainsworth et al (66) also reported the same results as our study.

The crude protein content varied from 6.6 to 9.76%. The regression analysis results showed significant ($P<0.05$) effect of SMBF concentration whereas there was a non-significant ($P>0.05$) effect of feed moisture content on crude protein content and the R^2 was 0.8911.

As we know, legumes contain more protein content than cereals (67) so crude protein content increased as a function of increasing rate of SMBF fortification. It is noticeable that it can be anticipated the amino acid profile of final extrudates has changed from almost non-existent to essential ones such as lysine (67). This matter positively affects the protein quality of these kinds of snacks, since cereal grains are deficient in this amino acid (68).Our findings are in accordance with Anton et al. (31) whose fortified corn starch-based extrudates with common bean. Pastor-Cavada et al. (69), Sade and Aderonke (70) and Ajibola et al. (65) also declared that protein content increased significantly with the addition of legume. Germination also has an effect on protein content, as it extended the protein content increased. As carbohydrates used as energy source during germination protein content of extrudates may increase (71).

Crude protein level may also affected by feed moisture content. It means that the protein content of extrudated increased as feed moisture increased and then decreased in upper levels of moisture content (Fig. 10). Stojceska et al. (39) also mentioned it in their study.

Protein digestibility is an important factor to assess the protein quality and nutritional properties of a food product. Digestible crude protein (DCP) of extrudates ranged from 13.05 to 46.68. The regression analysis results showed non-significant (P>0.05) effect of both SMBF concentration and feed moisture content on DCP. The model was non-significant (P>0.05) too. DCP didn't change by increase in SMBF concentration and feed moisture content, too. Ainsworth et al. (66) mentioned that DCP didn't increase by addition of protein source to snacks. They concluded that higher fibre content due to protein source addition is the reason that DCP values not increase and also this supplementation might be expected to reduce digestion of protein.

In many cases protein digestibility improved after processing due to reduction or omission of anti-nutrient components such as phytic acid, tannins and poly phenols which interact with protein to form complexes. So, degree of cross-linking increases, protein solubility decreases and finally the probability of proteolytic attack diminishes (72; 73).

Extrusion process caused higher increase in DCP content in comparison with the other processing methods due to its efficiency to reduce antinutrient components (71).

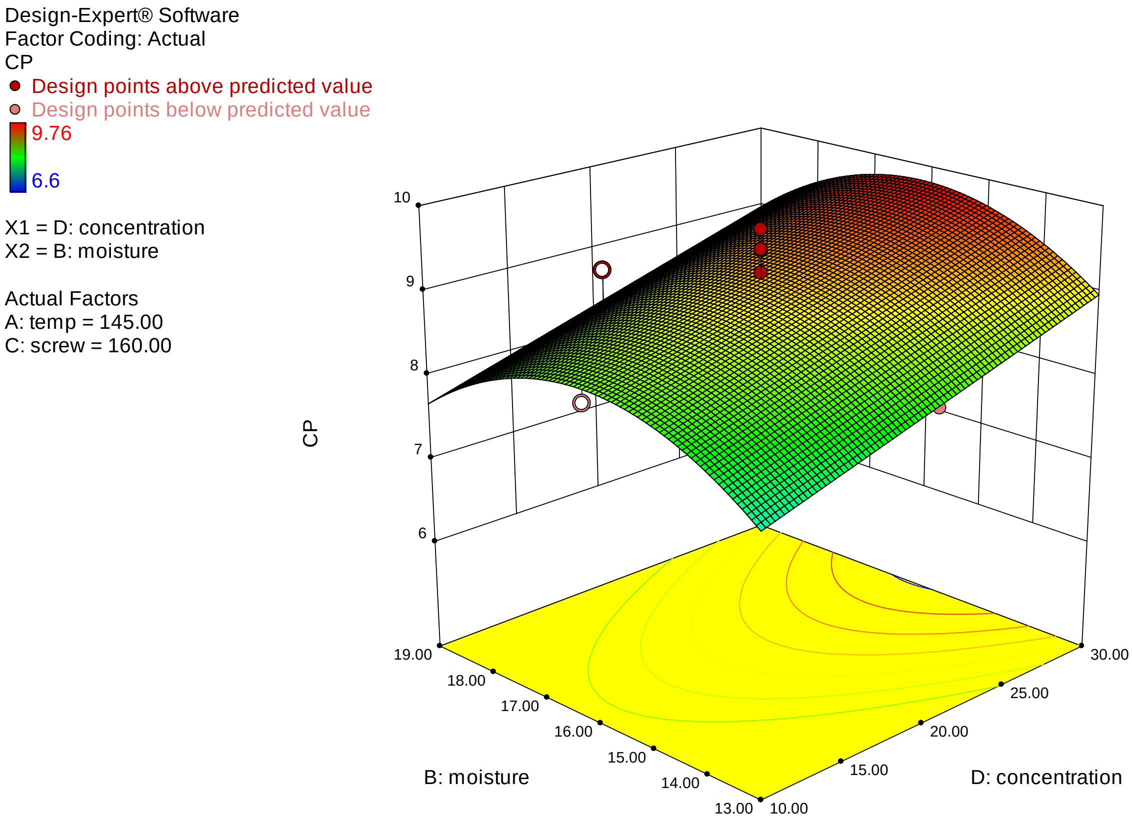

Fig 10. Effect of feed moisture and SMBF additionon product CP value.

Conclusion

Extruded products based on whole corn with the addition of SMBF may have some advantages. Although they have more nutritional quality than traditional extrudates including corn flour. These type of extrudates contain small amount of gluten which can almost be nominated as ''free gluten'' products. Finally they have very low amounts of anti-nutritional components and show better chemical composition since they have higher contents of proteins, fiber and minerals.

Feed moisture content increased the WAI, but had an opposite effect on the WSI and OAI. Material ratio was found to increase the WAI but deducing trend was observed for WSI and OAI. The high expansion ratio and low bulk density were observed at low feed moisture. Increased feed moisture increased in hardness of extrudate. The products with high expansion ratio and low product density, which generally are good characteristics of extruded snack, were produced at low feed moisture. Optimized formulation should include 16% moisture content and about 20% SMBF to corn ratio.

Research highlights:

1. The nutrition and physical properties of germinated mug bean-corn extradites were improved.

2. Due to lack of lysine in cereals, legumes can be used in food formulations. So many supplements contain grains and seeds are good for each other.

3. The germination process enhanced the nutritional characteristics of crops.

4. functional properties of extruded snacks are affected by the addition of mung bean sprouts and extrusion conditions.

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