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FUNCTIONAL PROPERTIES OF CORN EXTRUDATES ENRICHED WITH SESAME SEED

Nooshin Nikmaram[1], Mohammad Hassan Kamani[2]
[1] *Department of Food Science and Technology, Faculty of Agricultural Engineering, Islamic Azad University of Sabzevar, Sabzevar, Iran*
[2] *Young Researchers and Elite Club, Sabzevar Branch, Islamic Azad University, Sabzevar, Iran*

ABSTRACT

The aim of this manuscript was to study the effects of extrusion variables (screw speed and barrel temperature) on the functional properties of corn-sesame extruded products. Extrudates products were obtained with the addition of sesame seed at the levels of 0–30% to the mixture of corn grits and flour using a twin-screw extruder. Box–Behnken design-response surface methodology (BBD-RSM) was applied to optimize the effects of formulation and extrusion parameters. We found that sesame seed level factor had an effect on water absorption index (WAI). WAI was reduced up to 15% increase in sesame seed. However, a higher level of sesame seed resulted in raising WAI. The water solubility index of extrudate decreased significantly (p<0.05) with sesame seed level and increased with screw speed. The oil absorption index also reduced as sesame seed increased but increased with the increment of screw speed. In general, the incorporation of a sesame seed to corn extrudate resulted in the lower functional properties

Key words: Extrusion cooking, oil absorption, water absorption, water solubility.

INTRODUCTION

Human is the center of economic, social, cultural development and nutrition needs of all living creatures. Suitable nutrition has found a high position during the last decades due to changes in disease patterns. An appropriate nutrition pattern is a significant factor in the prevention of some diseases such as diabetes, cardiovascular disease, obesity and lipid disorders and this is effective from birth to death. Research results indicate that the cardiovascular diseases within the middle-aged people are rooted in their childhood nutrition [17].

Extrudate snack is one of the refreshments that in kids who are in need of nutritious food elements for their growth can cause pseudo-satiation. Despite their low nutritional value, due to their ease of use and maintenance have been strongly attractive for people especially children and adolescents. On the other hand, sesame seed is an invaluable food rich in manganese, copper, calcium, magnesium, iron, phosphorus, vitamin B1, zinc and dietary fiber [14]. So the enrichment of this product with sesame seed to produce a functional food may increase its nutritional value.

Functional food science and technology in today's concept have been proposed from 1980 for enriched products in Japan and have been developed to the present time [12, 15, 25]. Functional foods are products derived from foods that in addition to their nutritional values, promote normal physiological conditions or mental functioning and they are effective in the prevention of disorders that can lead to various diseases [4, 23, 28]. Extruded products enriched with sesame seed is also a functional product because sesame seed is rich in protein, essential fatty acids, phenolic compounds and antioxidants, vitamins and minerals that can improve the nutritional properties of snacks.

Extrusion technology is one the largest food processing technologies that is used since the mid-1930s to produce breakfast cereals, ready-to-eat snacks, protein food processing and pet feeds [11]. The advantages of extrusion process include gelatinization of starch, increased soluble dietary fibres, destruction of anti-nutritional factors, it also retains natural colours and flavours of foods and leads to a reduction of lipid oxidation and contaminating microorganisms [22].

The aim of this research was to study the effect of extrusion conditions (screw speed and extrusion temperature) and sesame seed level on some functional properties including water absorption, water solubility and oil absorption indices of corn and corn–sesame based extrudates.

MATERIALS AND METHODS

Materials

Sesame seed, variety *Dezful* was purchased from Karaj's seed and plant improvement Institute (Karaj, Iran) and yellow corn grits and yellow corn flour were purchased from Gold Cluster Company (Mashhad, Iran).

Sample preparation

For mixtures preparation, whole sesame seed was mixed with corn grits and corn flour at levels of 0, 15 and 30%. The percentages of added sesame seed were chosen based on several pre-testes that were done before starting main examination and total evaluation on recent research. The blended samples were adjusted to the desired moisture content by spraying calculated amounts of distilled 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 [16].

Extrusion cooking

Extrusion was performed in a twin-screw laboratory extruder, (DS56-III, Jinan Saixin Food Machinery, China) with three independent temperature control zones. The barrel diameter and L/D ratio were 64 mm and 12:1, respectively and died diameter was 3.6 cm. Constant feeding rate was kept throughout the experiments. Steady-state conditions were reached after 20 min, after which samples were collected. The cylindrical extrudates were dried at 50°C for 24h until the final moisture of 5% (±1%) using a hot air dryer (101-1EBS, SJIA LAB, China). The extrudates were cooled to room temperature and sealed in polyethylene bags until analyzed.

Water absorption and solubility indices

The water absorption index (WAI) and the water solubility index (WSI) were determined using the procedures described by Lazou and Krokida [16]. A 0.5 g ground extrudate was dispersed in 5 mL distilled water in a weighed 15 mL glass centrifuge tube (Sorvall Model RC-2, Norwalk, Conn, USA) and then agitated on a Vortex mixer for 2 min. The dispersion was centrifuged at 700 g for 20 min. The supernatant was poured into an evaporating dish of known weight. The supernatant was poured into an evaporating dish of known weight for determination of its solid content. After carefully removing the supernatant, sediment was weighed. WAI and WSI were calculated as:

$$\mathrm{WAI} = \frac{\text{Weight of Sediment}}{\text{Weight of Dry Solids}} \qquad \text{(Eq. 1)}$$

$$\mathrm{WSI} = \frac{\text{Weight of Dissolved Solids in Supernatant}}{\text{Weight of Dry Solids}} \times 100 \qquad \text{(Eq. 2)}$$

The results presented are the mean values of three replications.

Oil absorption index

Oil absorption index (OAI) was determined according to Lazou and Krokida [16]. 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, left for 30 min and centrifuge for 20 min at 700 g; the volume of the free oil was read andOAI calculated as follows:

$$OAI = \frac{volumeofoilabsorbed}{weightofthesample} \qquad \text{(Eq. 3)}$$

Experimental design

Statistical analyses were conducted using a Box–Behnken design extrudate in 17 runs of which were for the centre point, and eleven were for a non-centre point. The five independent variables considered were sesame seed content (0, 15 and 30%), screw speed (140, 180 and 220 rpm) and barrel temperature (120, 140 and 160°C). The independent variables are shown in Table 1.

Table 1. Process variables used in the Box–Behnken design for three independent variables

Run	Screw speed [rpm]	Temperature [°C]	Sesame seed level [%]
1	140	160	15
2	180	140	15
3	220	140	30
4	140	120	15
5	180	160	30

6	180	140	15
7	180	140	15
8	180	140	15
9	180	120	30
10	180	120	0
11	220	140	0
12	180	160	0
13	180	140	15
14	220	160	15
15	140	140	0
16	220	120	15
17	140	140	30

RESULTS AND DISCUSSION

Water absorption index (WAI)

The WAI determines the amount of water absorbed by the granule or starch polymer after swelling in excess water. In other words, WSI can be used as an indicator for the gelatinization [2, 16, 24]. Sesame level was found to be the only factor that had a significant effect ($p < 0.05$) on WAI. Stojceska et al. [26] reported a similar result, they incorporated brewer's spent grain (BSG) by-products into extrudates and found that only WAI was related to the level of BSG. In this study, in the range of 0 to 30%, WAI decreased with increasing sesame up to 15%, it increased after 15%as illustrated in Figure 1. The WAI experimental values for corn–sesame extrudates ranged from 2.92 to 5.3 g/g sample. Adding brewer's spent grain by-products decreased WAI due to an increase in dietary fiber levels [26]. The addition of cauliflower to the cereal based ready-to-eat expanded snacks had similar results [27], where WAI showed a high correlation with the level of cauliflower as a result of increasing fiber content. Filli et al. [8] explained the decreased WAI with an increase in the level of soybean flour due to oil in soybean which interfered with water uptake. Dilution of starch in rice pea blends is another reason described by Singh et al. [21, 22] for a decrease in WAI with the addition of pea grits in the extrusion of rice. Lazou and Krokida [16] reported that WAI value of corn–lentil extrudates decreased as the legume proportion increased.

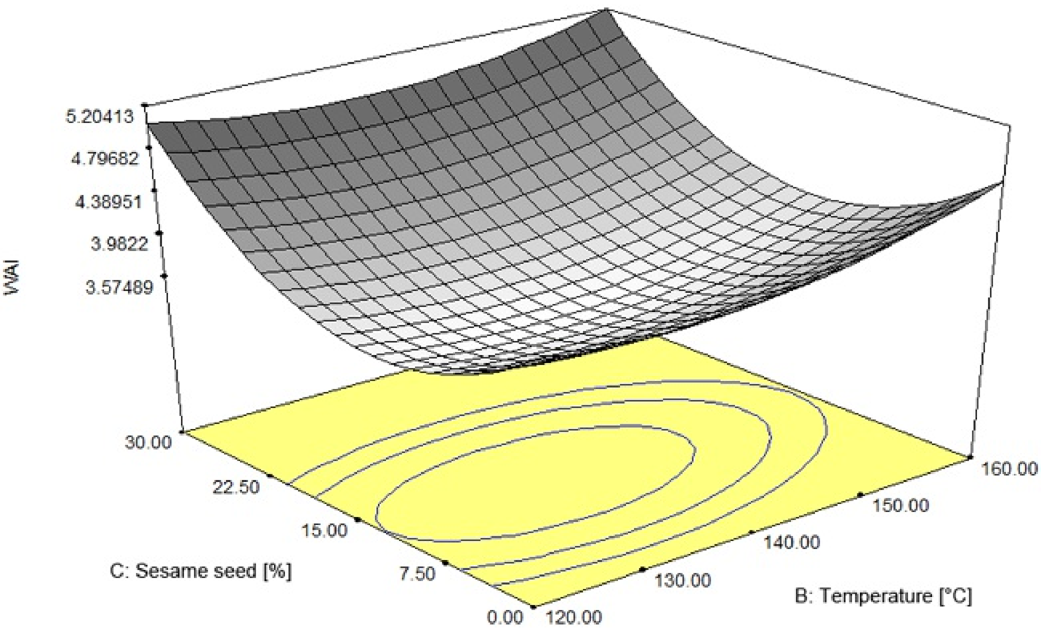

Fig. 1. Response surface plot for WAI as a function of sesame seed level and temperature at 180 rpm screw speed

On the other hand, increase in WAI after 15% was probably due to an increment of protein and fiber content. As proposed by Chang et al. [5], protein denaturation and swelling of fibers can be responsible for increased WAI of extrudate products. Similar findings were quoted by Pelembe et al. [19]; they stated that WAI rose with an increase in the percentage of cowpea in sorghum extrudates because of higher water solubility of cowpea proteins compared with sorghum proteins. Deshpande and Poshadri [6] reported that WAI of the extrudates is increased as chickpea and cowpea flours in the composite flour increased. Sacchetti et al. [20] observed high values of WAI in products with large chestnut flour (CF) that was probably due to the sucrose content of chestnuts.

Water solubility index (WSI)

The WSI measures a number of soluble molecules, which is related to the degree of starch conversion during extrusion. As described by Sriburi and Hill [24], WSI determines the quantity of free polysaccharide or polysaccharide released from the granule after addition of excess water, and it can be used as an indicator for the dextrinization.

The results indicated that linear effects of both sesame seed level and screw speed were significant. The effect of sesame seed level and screw speed on WSI of extrudates is shown in Figure 2. The WSI reduced significantly (p < 0.005) with increasing sesame seed level that can be related to the incorporation of proteins in extrudates, as proposed by Lazou and Krokida [16]. They explained that during extrusion cooking, loss in protein solubility occurs due to denaturation process resulting in structural changes that enable hydrophilic groups such as – OH, $-NH_2$, –COOH and –SH to form cross-links with starch so that WSI would decrease because of the increment of protein content. Zazueta-Morales et al. [29] observed that the WSI decreased when the $Ca(OH)_2$ concentration increased. The lowering of WSI seems to be as a result of the formation of complexes between starch and $Ca(OH)_2$ which caused swelling of the starch granules, along with WSI decrease.

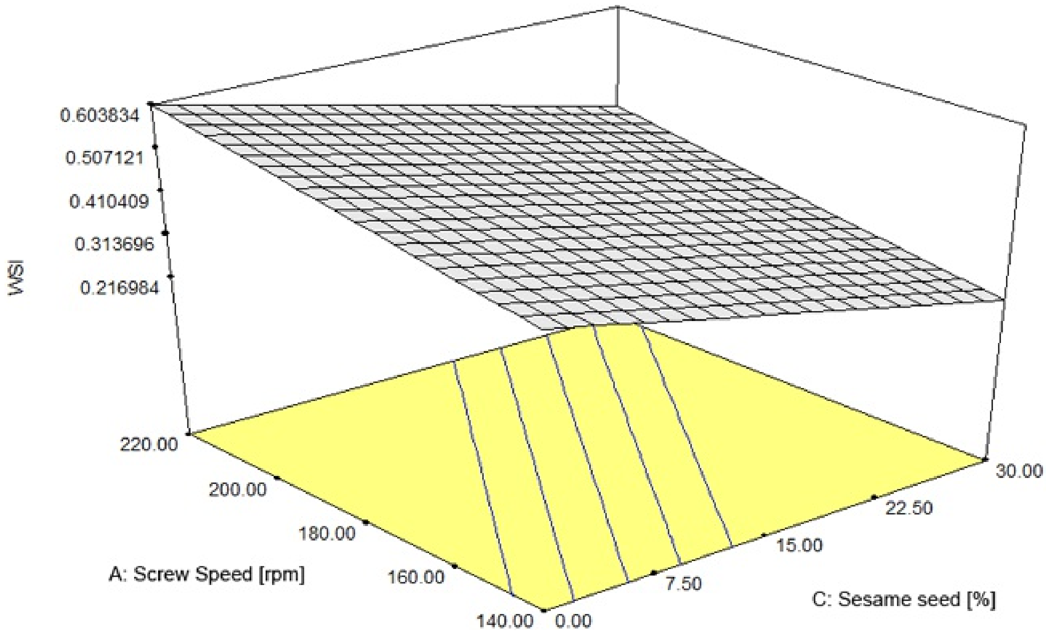

Fig. 2. Response surface plot for WSI as a function of sesame seed level and screw speed at 140°C

A number of studies have shown that WSI increased after food by-products were added to extrudate snacks. Altan et al. [2, 3] reported that WSI increased as the percentage of tomato pomace increased that could be attributed to the modification of fiber presence in pomace. Sacchetti et al. [20] obtained similar findings as an increment of chestnut flour.

The WSI raised screw speed increased, and this increase was more pronounced especially at high sesame seed levels (p<0.05). The values of WSI ranged from 0.2 to 0.56 g/100 g sample for corn–sesame extrudates. It was stated that increase in screw speed can lead to higher SME, and accordingly more degradation of macromolecules is caused. Therefore small molecules with higher solubility were produced and resulted in an increase in WSI [18]. Gujral et al. [9] also speculated similar effects for screw speed on WSI among sweet corn and flint corn grits extrudates in the range of 100 to 150 rpm. Jin et al. [13], Altan et al. [3], Mezreb et al. [18], Ainsworth et al. [1] quoted similar phenomena.

Oil absorption index (OAI)

Statistical analyses showed that the oil absorption index of extrudates was mostly dependent on sesame seed level (p<0.05). Screw speed also has significant effects (p<0.05) on OAI. The impact of these two variables on OAI is shown in Figure 3. Increasing the level of sesame seed resulted in lowering the OAI, but increased with increase in screw speed. Maximum OAI values occurred at highest screw speed value for the 0% sesame seed content. Lower absorption of oil by the addition of sesame seed that is rich in fat may be due to the high-fat content of final extrudate product as described by Deshpande and Poshadri [6]. Our result is in agreement with Lazou's and Krokida's study [16], who incorporated lentil to corn extrudates and observed lower OAI. They concluded that addition of protein resulted in OAI reduction. Similar effects have been noted by Gujska and Khan [10] for bean extrudates.

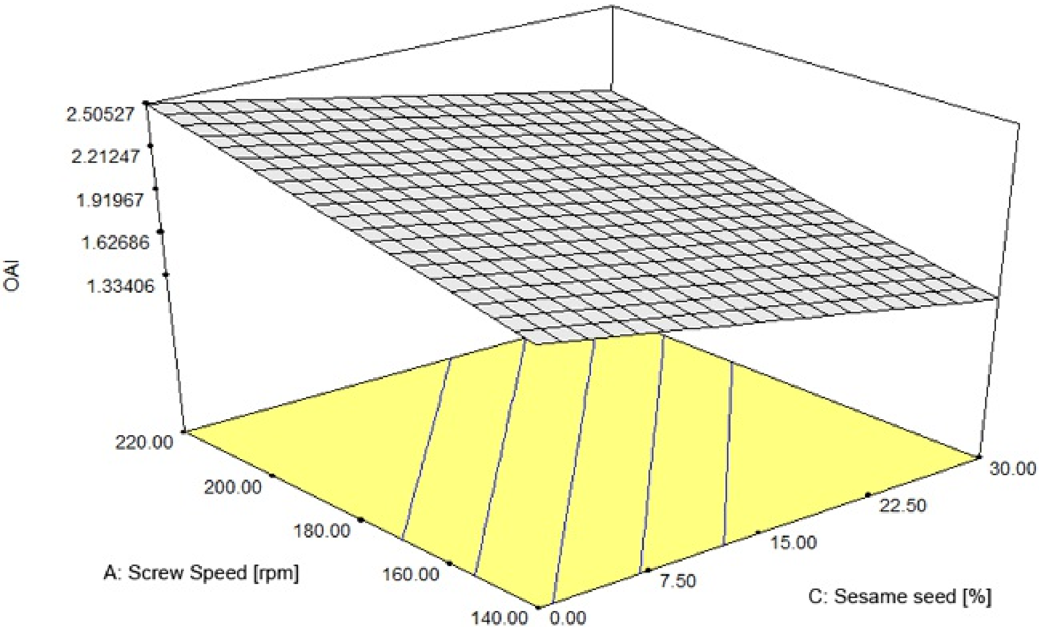

Fig. 3. Response surface plot for OAI as a function of sesame seed level and screw speed at 140°C

As proposed by Gujral et al. [9] increment of screw speed led to the severity of thermal treatment. The higher the extrusion temperature, the more degree of cooking of extrudates [7], resulted in the formation of smaller molecules because of starch dextrinization. The presence of these molecules can be responsible for the increase in OAI [16].

CONCLUSION

The idea to incorporate sesame seed to corn extrudate was motivated by the need to improve nutritional value and functional properties of corn extrudate products. The results showed that functional properties were found to be most dependent on sesame seed level and screw speed. Screw speed had no significant effect on WAI while increased WSI and OAI. The addition of sesame seed resulted in a reduction in WSI and OAI and also WAI up to 15%, however, for more percentage of sesame WAI increased. Barrel temperature had no significant effect on these indices. The effect of increasing sesame seed content was greater than the effect of screw speed on functional properties. Comparatively, extrudates from corn alone had higher values of functional properties than those with sesame content.

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Nooshin Nikmaram
Department of Food Science and Technology, Faculty of Agricultural Engineering, Islamic Azad University of Sabzevar, Sabzevar, Iran
Islamic Azad University of Sabzevar
Sabzevar, Khorasan Razavi Province
Iran
P.O. Box 9618814711
Phone: +98 938 1669927
Fax: +98 571 2647513
email: nooshin.nikmaram@gmail.com

Mohammad Hassan Kamani
Young Researchers and Elite Club, Sabzevar Branch, Islamic Azad University, Sabzevar, Iran
Islamic Azad University of Sabzevar
Sabzevar, Khorasan Razavi Province
Iran
P.O. Box 9618814711
Phone: +98 938 1669927
Fax: +98 571 2647513
email: mohammadh.kamani@gmail.com
