OPEN ACCESS
Saudi Journal of Engineering and Technology
Abbreviated Key Title: Saudi J Eng Technol
ISSN 2415-6272 (Print) |ISSN 2415-6264 (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: https://saudijournals.com

Original Research Article

Extrusion: A Novel Technique for Improvement of Dietary Fiber Functionality in Oat Bran

Ghulam Moheudin[1], Muhammad Kamran Arshad[1*], Hafiza Anam Asghar[1], Mehjabeen[1], Maria Alvi[1], Ushna Momal[1], Firdous Elahi[1]

[1]National Institute of Food Science & Technology, Faculty of Food, Nutrition and Home Sciences, University of Agriculture Faisalabad, Pakistan

DOI: 10.36348/sjet.2021.v06i12.006 | **Received:** 17.11.2021 | **Accepted:** 21.12.2021 | **Published:** 27.12.2021

***Corresponding author:** Muhammad Kamran Arshad

Abstract

Cereals are used as staple food in the world because they provide more energy and important source of vitamins, minerals, protein and carbohydrates. Oat is considered important cereal cultivated in different regions due to its ample source of soluble dietary fiber. Bran is the outermost layer of the grain which contains the appreciable amount of soluble dietary fiber called β-glucan helpful in lowering cholesterol and maintaining glucose level. Due to the health benefits of fibrous material from oat bran it gained more importance globally and has been added in different food items. But incorporation of fibrous material in food items negatively affects the characteristics of product ultimate acceptance. To improve the functionality of fibrous material, different methods are applied such as addition of chemicals and enzymes but they did not gain much popularity because people demand organic foods. So, the current study was designed to improve the functionality of fibrous material through extrusion cooking as it is more effective than other techniques. Proximate analysis expressed that oat bran had moisture, protein, fat, ash and fiber content as 8.25±0.04%, 14.15±0.07%, 6.12±0.05%, 2.50±0.10% and 3.55±0.23%, respectively. Extrusion of oat bran was done by using the barrel exit temperature 120˚C, 140 ˚C and 160˚C, screw speed 100rpm, 150rpm and 200rpm and feed moisture was 20%, 30% and 40%. Extruded bran was investigated for total dietary fiber, soluble dietary fiber and insoluble dietary fiber. Extrusion parameters had showed positively significant ($P<0.01$) effect on dietary fiber content, β-glucan content and extractable β-glucan content. In conclusion, current research showed that extrusion treatment of oat bran results in increased availability of fiber.

Keywords: cereals, oat, proximate composition, extrusion, dietary fiber, β-glucan.

1. INTRODUCTION

The mean of word cereals is grain and it is derived from the Latin term "cerealis". It is organically a natural product consists of germ, endosperm and outer layer is known as caryopsis. Cereal grains are main staple food crops as it provides valuable energy sources than any other crops and grow in greater quantities worldwide. Vitamins, carbohydrates, oils, fats, protein and minerals are the main components of whole grain in their natural form. These crops provide more food than any other crops for human consumption. It comprises 65-75% starches except from moisture content and cellulose of their total weight, 6-12% proteins, 1-5% fat as well as traces of vitamins and minerals. People fulfil more than half percentage of the energy requirements by eating the cereal grains, therefore it is considered as a principal component of human diet (Sarwar *et al.*, 2013). Oat is known as the principal cereal crop of the world. Oat belongs to *Poaceae* family like other grain crops and also known as "*Javi*" or "*Jai*". Bran is the uppermost covering of cereal grains which is hard enough and has a potential source of thousands of phytochemicals such as flavonoids, phenolics, pigments, dextran and β-glucan. Bran is the major source of dietary fiber. Fiber helps intestine to remove impurities which are not healthy for human body (Kaur *et al.*, 2012). Oat bran has health beneficial components which are helpful for lowering down the cholesterol level and coronary heart diseases, blood pressure, diabetes and cancer risk is also minimized by bran (Inglett and Chen, 2012). Different techniques are used to modify the properties of cereals bran before addition to final product. Physical, chemical and enzymatic modification of fibers has been studied as a strategy to improve their function. Extrusion causes the cooking of uncooked food material by applying high temperature, pressure and shear powers to cook the food. Extrusion cooking has many benefits over other technologies due to their low cost, high speed, high productivity, versatility and energy savings. The extrusion process results in extra alterations like formation of starch gel, cross-linking of protein molecules and production of flavor (Zhang *et al.*, 2011). Due to the thermo-mechanical properties of the extrusion cooking, the solubility and insoluble components of the fiber are redistributed (Gualberto *et al.*, 1997). Extrusion cooking inactivates unwanted enzymes, inactivates some anti-nutrients and sterilizes the final product and maintains the natural color and flavor of the food. Extrusion also reduces the number of microorganisms and improves protein digestibility and biological value (Nikmaram *et al.*, 2015). Current research is mainly focused to fulfil the objectives of improvement in functionality of oat bran through extrusion by focusing on different parameters of extrusion. For this purpose, oat is subjected to proximate analysis composition and estimation of different dietary fiber parameters by different extrusion parameters.

2. MATERIAL AND METHODS

Oat grains were acquired from the nearby local market. Every one of the raw materials and reagents utilized for the study were acquired from the Grain Science and Technology Laboratory of NIFSAT, University of Agriculture, Faisalabad.

2.1. Preparation of oat bran

Processing of grains and outer layer parting were done in the milling room of (NIFSAT). Cleaning and sizing of the material was done in the initial step to eliminate the tidy, waste, rocks, different particles and other undesirable constituents. Removal of hull from the oats was done the through dehuller machine in the second step. The external structure of the groat was isolated. The brighter oats are isolated and groats are taken for moreover steps. In the last step groats got after outer cover was processed with miller. The oat outer layer was isolated from flour in a few granulating and sieving activities to a grainy portion (grain) and fine division.

2.2. Proximate analysis of oat bran

Oat bran is subjected to proximate analysis including moisture, ash, crude fat, crude protein and crude fiber by following the methods of AACC, 2000.

2.3. Extrusion of Oat Bran

Extrusion of oat bran was done by using twin screw extruder. Pre-conditioning of bran was carried out to adjust the moisture content of the bran prior to the extrusion cooking. Extrusion was done by using the following parameters given in Table:1. The extrudate obtained were oven dried at 60–70˚C, for at least 20-30 minutes and thereafter, stored at room temperature for further analysis.

Table-1: Extrusion parameters

Treatment	Temperature ˚C	Screw speed rpm	Feed rate kg/h	Feed moisture %
T_1	120	100	50	20
T_2	140	150	100	30
T_3	160	200	150	40

2.4. Physical analysis of oat bran extrudate

Oat bran extrudate was subjected to dietary fiber analysis including total dietary fiber, soluble dietary fiber, insoluble dietary fiber, extractable dietary fiber and β-glucan content.

3. RESULTS AND DISCUSSION

3.1. Proximate analysis of oat bran

The results of proximate analysis results were given in Table 2 of oat. The results of proximate composition of oat bran was moisture 8.25±0.04%, protein 14.15±0.07%, ash content 2.50±0.10%, fat content 6.12±0.05% and fiber content 3.55±0.23%. The results regarding proximate composition are comparable with the results of Kaur *et al.* (2012) and Usman *et al.* (2010).

Table-2: Mean of proximate analysis of oat bran

Proximate composition	Quantity (%)
Moisture content	8.25±0.04
Crude Fiber	3.55±0.23
Crude Protein	14.15±0.07
Crude Fat	6.12±0.05
Ash content	2.50±0.10

3.2. Analysis of extruded oat bran

3.2.1. Quantification dietary fiber content

Mean squares regarding full regression for dietary fibre content of oat extrudates are presented in (Table 33). The results were observed to have significant effect for the barrel exit temperature and feed moisture. It can be followed that regression of dietary fibre content resulted in inconsiderate effects for screw speed variable using ANOVA. During extrusion cooking, significant variation was recorded in the DF of extrudates. This change in the DF profile of wheat bran is primarily attributed to extrusion variables and resulted in a shift from IDF to SDF.

Mean squares in regards to full regression for dietary fiber constituent of oat extrudates are shown in Table 3, 5 and 7, respectively. The outcomes were seen to have significant (P<0.01) impact for all variables used during extrusion on dietary fiber content. It is clear that all variables behave significantly for dietary fiber content of oat extrudates. From the regression coefficients, it is seen that all factors i.e. feed moisture, screw speed; barrel temperature has significant effect on the dietary fiber content of oat extrudates. Results show that all the variables positively affected the dietary fiber content. Speed, feed moisture and temperature also showed significant impact (P<0.1) on dietary fiber content in ANOVA Table 4, 6 and 8, respectively. The coefficient of determination (R^2) was noted as 87% demonstrates that the model was good fit. Mean results for all the treatments T_1, T_2 and T_3 shown in Table 9 it shows that T_3 treatment gives the better results in all aspects.

Table-3: Coefficients of variables for speed and dietary fiber content

Coefficient	Estimated S.E	T value	Pr(>|t|)
Intercept	9.333333	0.718022	12.999 0.0489 *
Speed	0.018000	0.004619	3.897 0.1599

Table-4: Analysis of variance for speed and dietary fiber content

SOV	DF	SS	MS	F value	Pr(>F)
Speed	1	1.62000	1.62000	15.188*	0.1599
Residuals	1	0.10667	0.10667		

Significant Degrees: Extremely Significant: 0 '***'; Moderately Significant: '**' 0.001; Marginally Significant: '*' 0.0 1; Significant: 0.05 '.'; Less Significant: 0.1''

Table-5: Coefficients of variables for moisture and dietary fiber content

Coefficient	Estimated S.E	T value	Pr(>|t|)
Intercept	9.333333	0.718022	12.999 0.0489 *
Moisture	0.09000	0.02309	3.897 0.1599

Table-6: Analysis of variance for moisture and dietary fiber content

SOV	DF	SS	MS	F value	Pr(>F)
Moisture	1	1.62000	1.62000	15.188*	0.1599
Residuals	1	0.10667	0.10667		

Significant Degrees: Extremely Significant: 0 '***'; Moderately Significant: '**' 0.001; Marginally Significant: '*' 0.0 1; Significant: 0.05 '.'; Less Significant: 0.1''

Table-7: Coefficients of variables for temperature and dietary fiber content

Coefficient	Estimated S.E	T value	Pr(>|t|)
Intercept	5.73333	1.62754	3.523 0.176
Temperature	0.04500	0.01155	3.897 0.160

Table-8: Analysis of variance for temperature and dietary fiber content

SOV	DF	SS	MS	F value	Pr(>F)
Temperature	1	1.62000	1.62000	15.188*	0.1599
Residuals	1	0.10667	0.10667		

Significant Degrees: Extremely Significant: 0 '***'; Moderately Significant: '**' 0.001; Marginally Significant: '*' 0.0 1; Significant: 0.05 '.'; Less Significant: 0.1''

Table-9: Mean Table for dietary fiber content

Treatments	DFC ± SE
T_1	10.23 ±0.82
T_2	11.93±0.76
T_3	12.83±0.92

3.2.2. Quantification of extractable dietary fiber

Mean squares regarding full regression for extractable dietary fiber of oat extrudates are presented in Table 10,12 and 14, respectively. The outcomes were seen to have significant (P<0.01) impact for the barrel temperature, screw speed and feed moisture on dietary fiber extractable. It is clear that the feed moisture, barrel temperature and screw speed behave significantly for extractable dietary fiber of oat extrudates. The coefficient of determination (R^2) was noted as 98% demonstrates that the model was excellent fit. From the regression coefficients, it is seen that all factors i.e. feed moisture, screw speed; barrel temperature has significant effect on the dietary fiber extractable of oat extrudates. Results show that all the variables positively affected the dietary fiber extractable. ANOVA showed significant (P<0.01) impact (P<0.05) on dietary fiber extractable due to speed and moisture and temperature presented in Table 11,13 and 15, respectively. Mean results for all the treatments T_1, T_2 and T_3 shown in Table 16 showed that T_3 treatment gave better results in all aspects.

Table-10: Coefficients of variables for temperature and extractable dietary fiber

Coefficient	Estimated S.E	T value	Pr(>|t|)
Intercept	0.8216667	0.0203443	40.39 0.0158*
Temperature	0.0017500	0.0001443	12.12 0.0524.

Table-11: Analysis of variance for temperature and extractable dietary fiber

SOV	DF	SS	MS	F value	Pr(>F)
Temperature	1	2.450e-03	2.450e-03	147	0.05239
Residuals	1	1.667e-05	1.667e-05		

Significant Degrees: Extremely Significant: 0 '***'; Moderately Significant: '**' 0.001; Marginally Significant: '*' 0.0 1; Significant: 0.05 '.'; Less Significant: 0.1''

Table-12: Coefficients of Variables for speed and extractable dietary fiber

Coefficient	Estimate S.E	T value	Pr(>|t|)
Intercept	9.617e-01	8.975e-03	107.15 0.00594**
Speed	7.000e-04	5.774e-0	12.12 0.05239*

Table-13: Analysis of variance for speed and extractable dietary fiber

SOV	DF	SS	MS	F value	Pr(>F)
Residuals	1	1.667e-05	1.667e-05		

Significant Degrees: Extremely Significant: 0 '***'; Moderately Significant: '**' 0.001; Marginally Significant: '*' 0.0 1; Significant: 0.05 '.'; Less Significant: 0.1''

Table-14: Coefficients of variables for Feed moisture and extractable dietary fiber

Coefficient	Estimate S.E	T value	Pr(>|t|)
Intercept	8.617e-01	7.975e-03	102.15 0.00594**
Moisture	6.000e-04	4.774e-0	11.12 0.05239*

Table-15: Analysis of variance for moisture and extractable dietary fiber

SOV	DF	SS	MS	F value	Pr(>F)
Moisture	1	2.450e-03	2.450e-03	147	0.05239
Residuals	1	1.667e-05	1.667e-05		

Significant Degrees: Extremely Significant: 0 '***'; Moderately Significant: '**' 0.001; Marginally Significant: '*' 0.0 1; Significant: 0.05 '.'; Less Significant: 0.1''

Table-16: Mean for extractable dietary fiber

Treatments	Extractable DF ± SE
T_1	0.94 ±0.16
T_2	1.02±0.20
T_3	1.08±0.23

3.2.3. Beta-glucan content

Mean squares in regards to full regression for ß-glucan content of oat extrudates are shown in Table 17, 19 and 21, respectively. The outcomes were seen to have significant impact for all the variables used during the extrusion process on ß-glucan content. It is clear that all variables behave significantly for ß-glucan content of oat extrudates. The coefficient of determination (R^2) was noted as 99% demonstrates that the model was excellent fit. From the regression coefficients, it is seen that all factors i.e. feed moisture, screw speed; barrel temperature has significant effect on the ß-glucan content of oat extrudates. Results show that all the variables positively affected the ß-glucan content. ANOVA also showed significant impact (P<0.01) on ß-glucan content due to speed, moisture and temperature as shown in Table 18,20 and 22, respectively. Mean results for all the treatments T_1, T_2

and T_3 shown in Table 23 showed that T_3 treatment gave better results in all aspects.

Table-17: Coefficients of variables for speed and ß-glucan content

Coefficient	Estimate S.E	T value	Pr(>|t|)
Intercept	7.3033333	0.0179505	406.86 0.00156**
Speed	0.0060000	0.0001155	51.96 0.01225*

Table-18: Analysis of variance for speed and and ß-glucan content

SOV	DF	SS	MS	F value	Pr(>F)
Speed	1	1.8e-01	1.8e-01	2700	0.01225
Residuals	1	6.7e-05	6.7e-05		

Significant Degrees: Extremely Significant: 0 '***'; Moderately Significant: '**' 0.001; Marginally Significant: '*' 0.0 1; Significant: 0.05 '.'; Less Significant: 0.1''

Table-19: Coefficients of variables for moisture and ß-glucan content

Coefficient	Estimate S.E	T value	Pr(>|t|)
Intercept	7.3033333	0.0179505	406.86 0.00156**
Moisture	0.0300000	0.0005774	51.96 0.01225

Table-20: Analysis of variance for moisture and ß-glucan content

SOV	DF	SS	MS	F value	Pr(>F)
Moisture	1	1.8e-01	1.8e-01	2700	0.01225
Residuals	1	6.7e-05	6.7e-05		

Significant Degrees: Extremely Significant: 0 '***'; Moderately Significant: '**' 0.001; Marginally Significant: '*' 0.0 1; Significant: 0.05 '.'; Less Significant: 0.1''

Table-21: Coefficients of variables for temperature and ß-glucan content

Coefficient	Estimate S.E	T value	Pr(>|t|)
Intercept	6.1033333	0.0406885	150.00 0.00424**
Temperature	0.0150000	0.0002887	51.96 0.01225*

Table-22: Analysis of variance for temperature and ß-glucan content

SOV	DF	SS	MS	F value	Pr(>F)
Temperature	1	1.8e-01	1.8e-01	2700	0.01225
Residuals	1	6.7e-05	6.7e-05		

Significant Degrees: Extremely Significant: 0 '***'; Moderately Significant: '**' 0.001; Marginally Significant: '*' 0.0 1; Significant: 0.05 '.'; Less Significant: 0.1'

Table-23: Mean for ß-glucan content

Treatments	ß-glucan content ± SE
T_1	7.23 ±0.45
T_2	7.37±0.78
T_3	7.8±0.51

3.2.4. Extractable ß -glucan

Mean squares in regards to full regression for extractable ß-glucan of oat extrudates are shown in Table 24, 26 and 28, respectively. The outcomes were seen to have significant impact for all the variables used during extrusion on extractable ß-glucan. It is clear that variable behave significantly for ß-glucan extractable of oat extrudates. The coefficient of determination (R^2) was noted as 65% demonstrates that the model was slightly good fit. From the regression coefficients, it is seen that all factors i.e. feed moisture, screw speed; barrel temperature has significant effect on the extractable ß-glucan of oat extrudates. Results show that all the variables positively affected the ß-glucan extractable. ANOVA showed significant impact ($P<0.01$) on extractable ß-glucan due to speed and moisture and temperature shown in Table 25, 27 and 29, respectively. Mean results for all the treatments T_1, T_2 and T_3 shown in Table 30 it shows that T_3 treatment gives the better results in all aspects.

Table-24: Coefficients of variables for temperature and extractable ß-glucan

Coefficient	Estimate S.E	T value	Pr(>|t|)
Intercept	35.73667	0.93584	38.187 0.0167*
Temperature	0.01450	0.00664	2.184 0.2734

Table-25: Analysis of variance for temperature and extractable ß-glucan

SOV	DF	SS	MS	F value	Pr(>F)
Temperature	1	0.168200	0.168200	4.7694	0.2734
Residuals	1	0.035267	0.035267		

Significant Degrees: Extremely Significant: 0 '***'; Moderately Significant: '**' 0.001; Marginally Significant: '*' 0.0 1; Significant: 0.05 '.'; Less Significant: 0.1''

Table-26: Coefficients of variables for moisture and extractable ß-glucan

Coefficient	Estimate S.E	T value	Pr(>|t|)
Intercept	36.89667	0.41286	89.368 0.00712**
Moisture	0.02900	0.01328	2.184 0.27337

Table-27: Analysis of variance for moisture and extractable ß-glucan

SOV	DF	SS	MS	F value	Pr(>F)
Moisture	1	0.168200	0.168200	4.7694	0.2734
Residuals	1	0.035267	0.035267		

Significant Degrees: Extremely Significant: 0 '***'; Moderately Significant: '**' 0.001; Marginally Significant: '*' 0.0 1; Significant: 0.05 '.'; Less Significant: 0.1''

Table-28: Coefficients of variables for speed and extractable ß-glucan

Coefficient	Estimate S.E	T value	Pr(>|t|)
Intercept	36.89667	0.41286	89.368 0.00712**
Speed	0.005800	0.002656	2.184 0.27337

Table-29: Analysis of variance for speed and extractable ß-glucan

SOV	DF	SS	MS	F value	Pr(>F)
Speed	1	0.168200	0.168200	4.7694	0.2734
Residuals	1	0.035267	0.035267		

Significant Degrees: Extremely Significant: 0 '***'; Moderately Significant: '**' 0.001; Marginally Significant: '*' 0.0 1; Significant: 0.05 '.'; Less Significant: 0.1''

Table-30: Mean Table for extractable beta glucan

Treatments	Extractable ß-glucan ± SE
T_1	37.6 ±0.78
T_2	37.1±1.20
T_3	38.6±1.03

CONCLUSION

Results of the present study demonstrated that functionality of oat bran can be improved through extrusion by focusing on different parameters of extrusion such as barrel exit temperature, screw speed, feed rate and moisture content etc. extrusion cooking results in increased availability of different types of dietary fiber such as total dietary fiber, extractable dietary fiber, β-glucan content and extractable β-glucan content. However, further research is needed in reference to other extrusion parameters and dietary fiber content.

REFERENCES

- AACC. (2000). Approved Methods of American Association of Cereal Chemists. Vol. I and II. St. Paul, MN.USA.
- Gualberto, D., Bergman, C., Kazemzadeh, M., & Weber, C. (1997). Effect of extrusion processing on the soluble and insoluble fiber, and phytic acid contents of cereal brans. *Plant Foods for Human Nutrition*, *51*,187-198.
- Inglett, G.E., & Chen, D. (2012). Antioxidant and pasting properties of oat β-glucan hydrocolloids. *Food and Nutrition Sciences*, *3*,827-835.
- Kaur, G., Sharma, S., Nagi, H., & Dar, B. N. (2012). Functional properties of pasta enriched with variable cereal brans. *Journal of Food Science and Technology*, *49*,467-474.
- Nikmaram, N., Kamani, M. H., & Ghalavand, R. (2015). The effects of extrusion cooking on antinutritional factors, chemical properties and contaminating microorganisms of food.

International Journal of Farming and Allied Sciences, *4*,352-354.

- Sarwar, M. H., Sarwar, M. F., Sarwar, M., Qadri, N. A., & Moghal, S. (2013). The importance of cereals (*Poaceae: Gramineae*) nutrition in human health: A review. *Journal of Cereals and Oilseeds, 4*, 32-35.
- Usman, S., Ali, S., Nasreen, Z., & Najim, A. (2010). Determination of biochemical composition of avena sativa (oat) and to estimate the effect of high fiber diet on hypercholesterolemic rats. *Bangladesh Research Publications Journal, 4*,312-19.
- Zhang, M., Bai, X., & Zhang, Z. (2011). Extrusion process improves the functionality of soluble dietary fiber in oat bran. *Journal of Cereal Science, 54*, 98-103.