Research Article

Comparative Study of Chapatis Made with Different Flour Combinations Using Organoleptic Properties and Image Analysis

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Abstract | Wheat is a widely used cereal around the globe. Over 759 million metric tons of wheat consumption was reported in the year 2020-21. Although, barley and oat are also nutrient rich but are less appealing to consumers due to their texture, taste, and chewability. This study aimed to prepare chapatis from wheat, barley, and oat flour mixed in different proportions to achieve a consumer acceptable combination. Gluten was also added to give better texture, chewability and taste. To test the likeliness of people, we tested 14 chapatis on a hedonic scale of 1-9 by ten participants. The panellist liked equally mixed wheat and gluten chapatis with an overall acceptability score of 7.6. Barley and gluten equally diverse chapatis are disliked most and the overall acceptability score is 4. We applied statistical analysis and image analysis. Statistical significance results are achieved using MANOVA. The image analysis for texture revealed similar results as those observed for chapatis made from similar flour. Our image analysis also proved the gluten's sticky binding property, i.e., filling the porous structure of chapatis.

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Introduction

A sedentary lifestyle and increased consumption of junk food can have many health implications. The prevalence of obesity, diabetes and cardiovascular diseases among adults has increased significantly in the last decade (Rhee, 2020). To overcome these issues, it is important to consume diets with appropriate proportions of various cereal grains. The consumption of whole cereal grains in our daily meals provides energy and a variety of nutrients including dietary fibre, protein, antioxidants, vitamins, and minerals essential for human health (Muhammad *et al.*, 2013).

Nutritionists suggest that consuming different cereal foods is better for health than relying solely on one food (Ejaz *et al.*, 2017). Oats (*Avena sativa* L.), barley (*Hordeum vulgare* L.) and wheat (*Triticum aestivum* L.)

are among the important cereal crops. Wheat serves as a primary staple food in Pakistan and many other countries. It provides instant energy and protein. Oat and barley have unique nutrition profiles among other cereals (Butt *et al.*, 2011). Oat's significant components are B-glucan, tocols, sterols, avenanthramide, phytic acid, and avenacosides. Avenanthramide is an antioxidant and its major source is oats (Tripathi *et al.*, 2018). These components protect against cardiovascular disease, gastrointestinal diseases, type 2 diabetes mellitus and cancer (Martinez-Villaluenga and Peñas, 2017). Oat is also a good source of high-quality protein (11-17%), which is nearly higher than other grains (Klose and Arendt, 2012). Oat is also a suitable choice for people with gluten intolerance. Barley consists of B-glucan, phytochemicals including phenolic acid, tocols, flavonoids, lignans, phytosterols, folate and many other bioactive compounds like dipeptidyl peptidase, inhibitory peptides, antiplatelet peptides, antibacterial peptides (Daou and Zhang, 2012; Idehen *et al.*, 2017). These compounds protect against metabolic and chronic diseases like coronary heart disease, type 2 diabetes, obesity, cancer and have cholesterol-lowering abilities (Guo *et al.*, 2020; Idehen *et al.*, 2017). Barley is far more impressive than oat for controlling diabetes as it reduces insulin level by 59-65%, while oats have been reported to reduce it by 29-36% (Behall *et al.*, 2005). The health benefit of wheat is imparted by its contents of phytochemicals, including enolic acids, carotenoids, tocopherols, alkylresorcinols, benzoxazinoids, and phytosterols and lignans (Luthria *et al.*, 2015). Wheat protects against diseases such as constipation, ischemic heart disease, diverticulosis, appendicitis, obesity, and diabetes (Awulachew, 2020) These cereals can be used in combinations to form a wide range of healthy products.

Among cereal products, chapatis are the most commonly consumed product in South Asian region. Though all these cereals are used to make chapatis, wheat flour chapatis are commonly consumed. Each grain has a different likeliness perspective and nutrient profile. Barley flour results in a hard blackish texture which is usually disliked. In contrast, oat chapatis are whitish, however people usually prefer brownish wheat chapatis. These two reasons deprived the majority people of two healthy kinds of cereal. Therefore, this study was planned to devised a way to create a balanced mixture of these cereals flours to get a consumer acceptable and healthy diet. A recent study deals with mixing spinach in wheat flour without allowing the texture to change and found that adding more than 30% decreased the consumer acceptability score (Waseem *et al.*, 2021). Another study added barley flour in wheat flour to bake biscuits and found that up to 40% is safe for keeping the quality of biscuits (Aly *et al.*, 2021).

Another essential ingredient, gluten is a high molecular weight seed storage protein commonly found in cereal grains, such as wheat, barley and rice (Diez-Sampedro *et al.*, 2019). In a study, people consuming a gluten-free diet (GFD) have more mercury, lead, and cadmium levels (Raehsler *et al.*, 2018). One-tenth of a million subjects were analysed for 25 years and data on dietary histories were collected periodically. It was found that gluten consumption was associated with 15% lesser chances of heart disease. Gluten long term intake was not related to cardiovascular diseases in healthy people, however gluten free diet results in less consumption of healthy grains which may affect cardiovascular diseases (Lebwohl *et al.*, 2017). Considering these studies, we planned to conduct a study by preparing the flour blend with wheat, oat and barley. This blend was further supplemented with gluten in different fractions. In this study, we studied user likeliness on a hedonic scale of 1-9 on different properties of chapatis made by mixing wheat, oat, barley and gluten with different combinations. Further, we applied image analysis to study the difference with different flour combinations.

Materials and Methods

Flour making process

Three different flours wheat, barley and oat were taken. These flours were used to make chapatis in different combinations as shown in Table 1. 66 grams of wheat, oat and barely flour were taken to make three different chapatis. Moreover, 18 and 33 grams of gluten were also added in some of these combinations as shown in Table 1. Though wheat flour has gluten in it, still we added extra gluten in a few combinations of wheat to observe its effect in comparison to other treatments where the gluten was added due to the replacement of wheat flour. Wheat flour already has gluten in it, if we add a small amount of extra gluten then the effect will be negligible. Therefore, we added gluten in high quantities to have a clear user response. These flour combinations were mixed with a suitable amount of water to knead the dough for making chapattis. All

the dough of different treatments were given stay time for half an hour.

Table 1: *Composition of different treatments to make chapattis.*

Study	Wheat	Oat	Barley	Gluten
W66 (S1)	66 g			
O66 (S2)		66g		
B66 (S3)			66g	
O48_G18 (S4)		48g		18g
O33_G33 (S5)		33g		33g
B48_G18 (S6)			48	18g
B33_G33 (S7)			33g	33g
W33_O33 (S8)	33g	33g		
W33_B33 (S9)	33g		33g	
O33_B33 (S10)		33g	33g	
W48_G18 (S12)	48			18
W33_G33 (S12)	33			33
W22_O22-B22 (S13)	22	22	22	
W17_O17_B17_G17 (S14)	17g	17g	17g	17g

Each study (S) shows the flour and quantity used. W: wheat, O: oat, B: barley, G: gluten. For example, W66 means 66 grams of wheat flour. W22_O22_B22 means 22 grams of wheat, oat and barley. S represent the sample chapatti name.

Each dough was molded to form balls and then sheeted with the help of a rolling pin. A griddle was placed on the stove for heating. The sheeted dough was then placed on hot griddle for 60 seconds on each side to make a chapatti.

Sensory analysis

Ten untrained sensory panelists analyzed the freshly prepared tortillas chapatis using a nine-point hedonic scale measuring food acceptability from like to dislike on a scale of 9-1, respectively. 9 shows extreme likeliness while 1 shows extreme dis-likeness and 5 shows a neutral response. Sensory panelists rate the parameters such as appearance, aroma, flavor, texture, chewability, folding ability and overall acceptability.

Statistical analysis

In this study we have multiple dependent (hedonic scale properties) and independent (flour combinations) variables. Therefore, we decided to use multivariate analysis of variance (MANOVA) test. MANOVA is an extension of ANOVA (analysis of variance), the difference is that MANOVA deals with multiple dependent variables. ANOVA is derived from student t-test which defines whether two or more populations (flour combinations) are statistically different from each other whereas t-test is only used for two populations. We have used following MANOVA tests.

- Wilks lambda
- Pillai's trace
- Hotelling-Lawley trace
- Roy's greatest root

These four tests combined the dependent variables in different ways to calculate the variance in data. The main difference between these tests is that Wilks' lambda and Pillai's trace are both based on the multivariate assumption, while Hotelling-Lawley trace and Roy's greatest root are not.

Imaging analysis

Imaging analysis was performed to compare the most liked chapatti as per hedonic scale with other chapattis with the help of Python 3.8.5 on windows 10, Intel(R) Core (TM) i7-8750H CPU @ 2.20GHz 2.21 GHz, 16 GB ram system. First, we crop patches of 1600px x 1600px at the center from all chapatti images, as shown in Figure 1. These patches contained noise because they were not produced under a controlled environment as there was a minute difference of lightning while capturing the image. Furthermore, some patches were more heated than others. These photos were then subdivided into four parts to overcome this issue. It reduced the noise such as black dots because of overheating. Patching also overcome the camera lightning issue as it suppressed the high intensity pixels and enhance the low intensity pixels. We converted the patches from RGB to CIELUV color space to better understand colors as shown in Figure 2. Further sharpening filter was applied to enhance the properties of CIELUV patches. The filter enhanced the textural properties of the images.

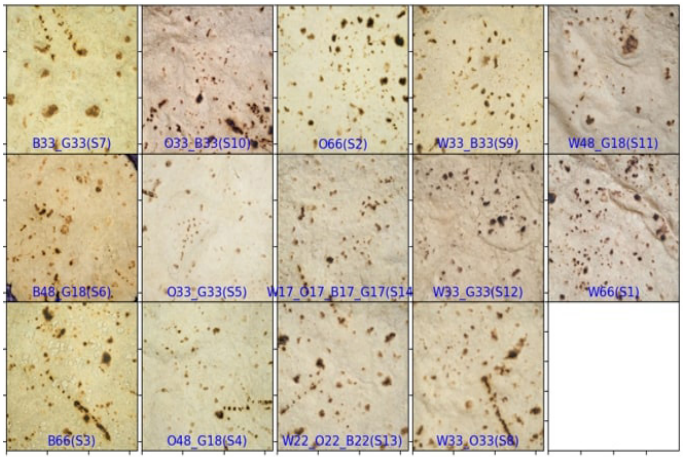

Figure 1: *1600 × 1600 patches of all chapatis.*

Table 2: *Average ratings by sensory panelists for evaluated chapattis.*

Flour combinations	W66 (S1)	O66 (S2)	B66 (S3)	O48_ G18 (S4)	O33_ G33 (S5)	B48_ G18 (S6)	B33_ G33 (S7)	W33_ O33 (S8)	W33_ B33 (S9)	O33_ B33 (S10)	W48- G18 (S11)	W33_ G33 (S12)	W22_ O22-B22 (S13)	WOBG17 (S14)
Appearance	6.4	7.2	4.8	6	5.5	5.3	4.4	5.4	7.4	6	6	7.6	5.2	6.2
Color	5.8	7.3	4.7	6	4.8	4.8	4.2	5.4	7	5.8	5.2	7.2	5.4	6.6
Texture	6	7.5	4.3	5.5	5.3	5.2	4.4	5.6	6	5.2	6.2	7.2	6	6
Folding ability	7	6.4	5.8	5.5	4.9	5.6	5.1	7.2	6.4	5.5	6.8	7.8	5.8	6.6
Taste/Flavor	6.6	5.7	5.7	5.2	4.5	5.7	3.8	6.4	5.6	6	5.6	7.8	5.6	6.2
Chewability	6.8	4.5	4.3	4.6	5	4.8	4.8	7	5	6	5.8	7	5	6
Overall acceptability	6.6	6.4	4.4	5.8	4.1	5.7	4	6.4	6.4	6.2	6.2	7.6	5.4	6.4

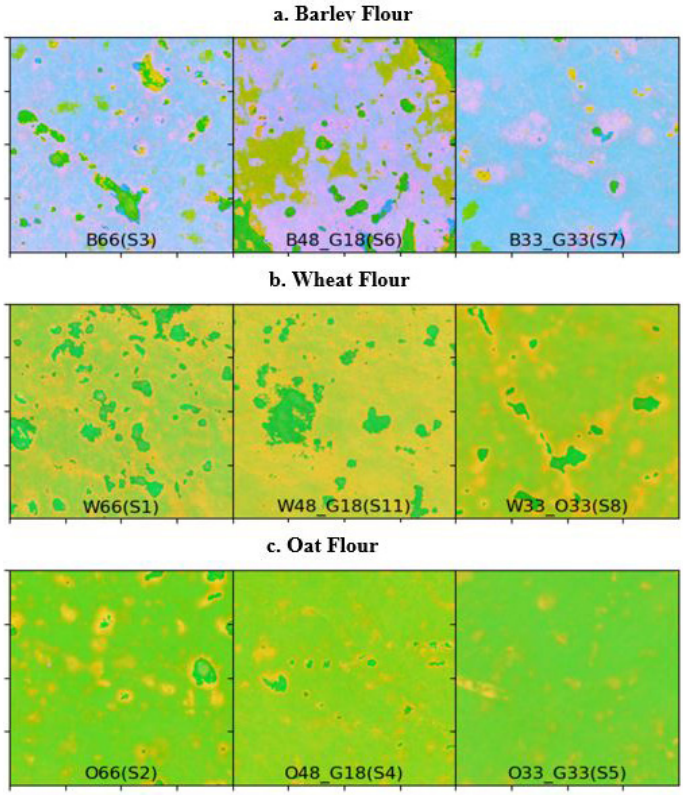

Figure 2: *Image analysis of chapatis. Chapatis of same flour combinations shows similar texture.*

Results and Discussion

Ten members panel analyzed 14 chapattis on a hedonic nine-point scale. Table 2 shows the response given by sensory panelists. The panelists were unaware of the type of chapatti. Most participants liked the wheat (S1), oat barley chapati (S13) made by mixing an equal amount of these flours. Panelists disliked barley chapati (S3), oat gluten equally mixed chapatis (S5) and barley gluten equally diverse chapatis (S7) and scored them the lowest overall acceptability of 4.4, 4.1 and 4.0, respectively, on the hedonic scale.

Overall, though oat chapati had a good-looking brown, whitish color but tearing and chewability were not good. The panelist liked the oat chapatis' appearance, texture, and color the most. In baking, the oat dough is not difficult to knead and sheeting with a rolling pin is neither difficult nor easy. In S4 treatment by adding 18 grams of gluten in oat chapati by reducing 18 grams of oat flour gave chapati a slight white color as shown in Figure 1. According to the consumer perspective as shown in Table 2, the addition of gluten did not significantly improve taste and chewability and decreased its appearance, color, texture, and folding ability. Oat 33 grams and gluten 33-grams chapati (S5) was extra whitish, unlike by most of the sensory panel personals. Color, texture, folding ability reduced on the hedonic scale by adding an excess of gluten and slightly increased chewability. Barley chapatis were hard in texture and black brownish in appearance. The dough was difficult to knead and was difficult to sheet with the rolling pin. Most sensory panelists did not like the appearance, color, texture and chewability, while few panelists slightly liked it. Most of the panelists believed that taste and flavor was neither bad nor good of barley chapati. Adding more gluten while reducing barley up to 33grams (S7) resulted in bad appearance and color, while the flavor was disliked by many as shown in Table 2. This chapati also had red spots inside which has greatly influenced consumer choice. Adding 33 grams of wheat flour in 33 grams of barley (S9) flour increased the appearance, color, texture, folding ability to a greater extent and slightly enhanced chewability while taste remained nearly the same as of barley 66 grams (S3) and barley 48 and gluten 18 grams (S6).

Adding 33 grams of wheat flour in 33 grams of oat flour chapati (S8) had a nearly similar appearance, color, and texture value to oat 33 grams and gluten 33 grams (S5). There was a massive improvement in chewability from oat 66 grams (S2) to O48_G18 (S4)

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and from O48_G18 (S4) to O33_G33 (S5) samples. Wheat chapati appearance, texture, folding ability, taste, chewability and was liked by everyone. Few panelists disliked the color of wheat chapati. Adding 48 grams of wheat flour in 18 grams of gluten (S11) did not impact overall. Increasing gluten amount to 33 grams and reducing wheat flour to 33 grams (S12) increased the appearance, color, texture, folding ability, taste/flavor, chewability to a greater extent from wheat 48 grams and gluten 18 grams (S11) chapati while to a lesser extent overall increase seen from whole wheat flour.

The addition of 33 grams of barley flour in 33 grams of oat flour (S8) had the appearance, color, texture in between oat and barley flour chapati. Folding ability is lesser, taste and chewability were better than both. Panelists did not like mixing wheat flour 22-grams, barley flour 22 grams, and oat flour 22 grams (S13). Oat, wheat, barley and gluten 17 grams each chapati (S14) was medium in texture and had little elasticity. Most panelists slightly liked the appearance, color, texture, folding ability, taste, and chewability.

Table 3: *MANOVA statistical results.*

Test name	F value	P value
Wilks' lambda	1.6705	0.0143
Pillai's trace	1.3990	0.0666
Hotelling-Lawley trace	2.0041	0.0041
Roy's greatest root	10.3145	0.00

The results shown in Table 3 indicate that there is a significant difference between the groups. The p-value is less than 0.05 except for Pillai's trace, which means that we can reject the null hypothesis that there is no significant difference between the groups. The Pillai's trace results showed that there is no significant difference at a significance level of 0.05.

Figure 2 shows the image analysis of selected chapatis. Wheat has a yellowish color without the extra addition of gluten. This texture enhances when 37% gluten is added and reduced when 50% gluten is added as shown in Figure 2B. A similar trend is observed in barely where gluten is already present naturally as depicted in Figure 2A. Figure 2C shows that in the oat flour without gluten, the surface is a bit rough and it got smoother with the addition of gluten. Gluten acts as a binder, holding chapatis fibers together and enhancing the stretching quality. In Figure 2, the rough torn able texture is filled with the addition of gluten. It looked like as gluten fills the space between the particles of chapatis which proved the gluten characteristics as a filler holding food together. Further, we can view that each flour has a similar colour appearance. All the barley flour has a bluish texture, wheat has a yellowish-green texture and oat had a greenish texture. These textures represent the ingredients of chapatis in CIELUV color space. Using this color space, the different texture of ingredients was separable visible to the human eye which was not possible with RGB color space.

In terms of nutrition and value addition wheat, oat and barley mixed chapati was the best combination as it has all the important micronutrients the three cereals provide (Biel *et al.*, 2020). Further, sensory parameters can be improved by using more combinations of flours and having a large sensory panel with prior training. Though there are different studies based on mixing of other products such as spinach with wheat flour to increase the nutritional profile (Waseem *et al.*, 2021). In our best knowledge, there is only one study that explained the likeliness based on the mixing of barley and oat with wheat. In the study the researcher got an overall acceptability of 7 on chapatis made of wheat flour only. Their acceptability rate is bit higher as compared to our one i.e., 6.4. Unlike our study, the researcher mixed other flour up to maximum of 15%, and they did not used gluten (Ejaz *et al.*, 2017). We observed that barley dough was difficult to prepare which was also observed in literature where authors mentioned that barley dough took 3x more time for preparation as compared to wheat dough (Gujral *et al.*, 2018).

Conclusions and Recommendations

Wheat is the most used food component worldwide and it contains a protein called gluten. In this study, we consider different flours combinations such as barley, oat, wheat with gluten. A panel of 10 members assessed the qualities of chapattis made using these flour combinations on a hedonic scale. It was indicated that adding gluten increased chewability. Most panelists like gluten-mixed wheat instead of wheat alone. Though gluten is not recommended for the user having celiac disease, it is recommended for a normal user as it reduces the impact of cardiovascular diseases. This study also examined chapattis appearance based on imaging techniques and found that chapattis of the

same flours have similar visual characters. Our image analysis also proved that gluten acted as a binder and filled the holes in chapatis.

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Novelty Statement

This study presents an approach in testing consumer preference for chapatis featuring a blend of wheat, barley, and oat flours, enhanced with gluten. Through image analysis, it further offers an insight into gluten's binding capacity in enhancing chapatis' texture and appeal.

Authors' Contribution

Hassan Anwar: Conducted experiment and collect data, wrote introduction, literature review and methodology.
Talha Anwar: Wrote results and discussion and finalize the manuscript.
Khurram Muaz: Critically reviewed and edited the manuscript.
Muhammad Riaz: Conceptualization and supervised the work.
Rabia Anwar: Reviewed and edited the manuscript.
All authors read and approved the final manuscript.

Conflict of interest
The authors have declared no conflict of interest.

References

Aly, A.A., F.E. El-Deeb, A.A. Abdelazeem, A.M. Hameed, A.A. Alfi, H. Alessa and A.F. Alrefaei. 2021. Addition of whole barley flour as a partial substitute of wheat flour to enhance the nutritional value of biscuits Arab. J. Chem., 14(5): 103112. https://doi.org/10.1016/j.arabjc.2021.103112

Awulachew, M.T., 2020. The role of wheat in human nutrition and its medicinal value. Glob. Acad. J. Med. Sci., 2(6): 50-54.

Behall, K.M., D.J. Scholfield and J. Hallfrisch. 2005. Comparison of hormone and glucose responses of overweight women to barley and oats. J. Am. Coll. Nutr., 24(3): 182-188. https://doi.org/10.1080/07315724.2005.10719464

Biel, W., K. Kazimierska and U. Bashutska. 2020. Nutritional value of wheat, triticale, barley and oat grains. Acta Sci. Pol. Zoot., 19(3): 19-28. https://doi.org/10.21005/asp.2020.19.2.03

Butt, M.S., N. Shahzadi, H. Suleria, T. Sultan and M.I. Chohan. 2011. Effect of dietary fiber in lowering serum glucose and body weight in sprague dawley rats. Funct. Food Health Dis., 1(8): 261-278. https://doi.org/10.31989/ffhd.v1i8.124

Daou, C., and H. Zhang. 2012. Oat beta-glucan: Its role in health promotion and prevention of diseases. Ompr. Rev. Food Sci., 11(4): 355-365. https://doi.org/10.1111/j.1541-4337.2012.00189.x

Diez-Sampedro, A., M. Olenick, T. Maltseva and M. Flowers. 2019. A gluten-free diet, not an appropriate choice without a medical diagnosis. J. Nutr. Metab., 2019: 2438934. https://doi.org/10.1155/2019/2438934

Ejaz, R., M.K. Sharif, I. Pasha, S. Abbas, A. Wadood and A. Amin. 2017. Barley and oat meal supplemented chapaties and its impact on serum biochemical profile in normal individuals. Biol. Sci. PJSIR, 60(1): 19-26. https://doi.org/10.52763/PJSIR.BIOL.SCI.60.1.2017.19.26

Gujral, H.S., B. Sharma and M. Khatri. 2018. Influence of replacing wheat bran with barley bran on dough rheology, digestibility and retrogradation behavior of chapatti. Food Chem., 240: 1154-1160. https://doi.org/10.1016/j.foodchem.2017.08.042

Guo, T., C. Horvath, L. Chen, J. Chen and B. Zheng. 2020. Understanding the nutrient composition and nutritional functions of highland barley (Qingke): A review. Trends Food Sci. Technol., 103: 109-117. https://doi.org/10.1016/j.tifs.2020.07.011

Idehen, E., Y. Tang and S. Sang. 2017. Bioactive phytochemicals in barley. J. Food Drug. Anal., 25(1): 148-161. https://doi.org/10.1016/j.jfda.2016.08.002

Klose, C. and E.K. Arendt. 2012. Proteins in oats, their synthesis and changes during germination: A review. Crit. Rev. Food Sci. Nutr., 52(7): 629-639. https://doi.org/10.1080/10408398.2010.504902

Lebwohl, B., Y. Cao, G. Zong, F.B. Hu, P.H. Green, A.I. Neugut, E.B. Rimm, L. Sampson, L.W. Dougherty, E. Giovannucci and W.C. Willett.

2017. Long term gluten consumption in adults without celiac disease and risk of coronary heart disease: Prospective cohort study. Br. Med. J., 357. https://doi.org/10.1136/bmj.j1892

Luthria, D.L., Y. Lu and K.M. John. 2015. Bioactive phytochemicals in wheat: Extraction, analysis, processing, and functional properties. J. Funct. Foods, 18: 910-925. https://doi.org/10.1016/j.jff.2015.01.001

Martinez-Villaluenga, C. and E. Penas. 2017. Health benefits of oat: Current evidence and molecular mechanisms. Curr. Opin. Food Sci., 14: 26-31. https://doi.org/10.1016/j.cofs.2017.01.004

Muhammad, H.S., F.S. Muhammad, S. Muhammad, A.Q. Niaz and M. Safia. 2013. The importance of cereals (Poaceae: Gramineae) nutrition in human health: A review. J. Cereals Oilseeds, 4(3): 32-35. https://doi.org/10.5897/JCO12.023

Raehsler, S.L., E.V. Marietta and J.A. Murray. 2018. Accumulation of heavy metals in people on a gluten-free diet. Clin. Gastroenterol. Hepatol., 16(2): 244-251. https://doi.org/10.1016/j.cgh.2017.01.034

Rhee, E.J., 2020. Prevalence and current management of cardiovascular risk factors in Korean adults based on fact sheets. Endocrinol. Metab., 35(1): 85-94. https://doi.org/10.3803/EnM.2020.35.1.85

Tripathi, V., A. Singh and M. Ashraf. 2018. Avenanthramides of oats: Medicinal importance and future perspectives. Phcog. Rev., 12(23). https://doi.org/10.4103/phrev.phrev_34_17

Waseem, M., S. Akhtar, M.F. Manzoor, A.A. Mirani, Z. Ali, T. Ismail, N. Ahmad and E. Karrar. 2021. Nutritional characterisation and food value addition properties of dehydrated spinach powder. Food Sci. Nutr., 9(2): 1213-1221. https://doi.org/10.1002/fsn3.2110