



Modification of Emulsifying Properties of Cereal Flours by Blending with Legume Flours

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ABSTRACT

Background: The effect of blend formation on emulsifying activity (EA) and emulsifying stability (ES) of some commonly used cereal and legume flours, using different oils, was studied.

Methods: The blends of wheat flour (WF), refined wheat flour (RWF) and maize flour (MF) were prepared by mixing with equal proportions of chickpea flour (CPF) (1:1w/w) in a kitchen blender and analyzed for EA and ES using coconut, canola, corn, rapeseed and sunflower oils.

Result: Statistically significant variations ($p < 0.05$) were observed in the emulsifying properties of the flours and their blends. The blending of cereal flours with CPF showed mixed responses of variation in emulsifying properties from those of the respective pure flours. The EA of the blends was found to be increased from those of the pure WF and RWF but decreased from those of the pure MF and CPF with some exceptions. However, the ES of the blends was decreased from that of the pure WF and increased from those of the pure RWF, MF and CPF. The data would be a valuable contribution to the literature regarding the improvement of functional properties of cereal foods.

Key words: Blend formation, Cereal flour, Emulsifying activity, Emulsifying stability, Functional properties, Legume flour.

INTRODUCTION

Cereal and legume flours are used as the main ingredient in bread, soup and sausages, cookies, pasta and fast foods (Bushuk 1986; Nawaz *et al.* 2018). The cereal-legume combination has always remained helpful in the preparation of balanced nutritional and functional foods. Functional properties are the intrinsic properties of flours that depend on their proximate composition particularly the quality and quantity of carbohydrates, lipids and proteins (Bajaj *et al.* 2018; Pomeranz 2012). The flours with relatively higher protein and lower starch content have been reported to possess higher values of oil absorption and emulsifying properties (Wu *et al.* 2009).

Emulsifying activity (EA) is the ability of the flour to form a stable emulsion by protein dispersion in the presence of oil and water while the emulsifying stability (ES) measures the persistence of the emulsion formed. EA is due to the ability of the flour to develop interactions between oil and water by reducing the surface tension after homogenization (Anton *et al.* 2009; Farooq and Boye 2011; Shad *et al.* 2011). The EA is entirely associated with the amino acid composition and structural arrangement of protein present in the flour. As proteins are the polymers of different types of amino acids, the ratio of hydrophobic/hydrophilic amino acids in the protein determines the EA and ES of a flour (Akinyede and Amoo 2009; Fasasi *et al.* 2006; Kim *et al.* 2020; Qamar *et al.* 2020). The proteins consisting of a suitable proportion of polar and non-polar amino acids show relatively good EA and ES than those containing a very high proportion of either the polar or non-polar ones (Chau and Cheung 1998; Fasasi *et al.* 2006). The required value of EA for a food formulation depends on the type and purpose of

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the food product to be prepared. The food products prepared with flours possessing relatively high EA and ES are helpful in the digestion of lipids in small intestine. Depending on the needs, the functional properties of the cereal flours can be improved by forming their blends with legume flours possessing a relatively different value of functional properties (Nawaz *et al.* 2015; Zeng *et al.* 2011). The blend formation may either increase or decrease the emulsifying properties as per the requirement of the food product (Arab *et al.* 2010).

The functional properties of cereal and other flours have been reported to be influenced by various processing techniques such as freeze-thaw, extrusion, cooking, roasting and blending (Feng *et al.* 2020; Hussain *et al.* 2018; Kaur *et al.* 2014; Tanwar *et al.* 2019). Previously, studies have been reported on the modification of various functional properties of different cereal and legume flours by the

formation of their blends (Badar 2013; Edema *et al.* 2005; Nawaz *et al.* 2015). However, a limited data is available regarding the modification of emulsifying properties of various cereal flours by the formation of their blends with legume flour using different oils. Therefore, the present study was planned to evaluate the variation in emulsifying properties of some commonly used cereal flours after forming their blends with legume flour using different oils. The study would be a valuable contribution to the literature regarding the improvement of functional properties of cereal foods and the preparation of nutritionally important functional foods.

MATERIALS AND METHODS

Sampling

The cereal flours including wheat flour (WF), refined wheat flour (RWF), maize flour (MF) and legume flour including chickpea flour (CPF) were purchased from the local market, brought to the laboratory and used for the analysis of emulsifying properties without further processing. The locally used cooking oils including rapeseed oil, corn oil, sunflower oil and refined canola oil were collected from Sultan Ghee industries Multan, Pakistan. The whole research work was carried out in a Research Laboratory at Bahauddin Zakariya University, Multan, Pakistan, during November 2019-March 2020.

Preparation of blends

The homogenous blends of the selected cereal flours were prepared by mixing equal proportions of legume flour (1:1w/w) in a kitchen mixer blender at a slow speed to avoid thermal fluctuations. The flours and their blends were subjected to analysis of emulsifying properties.

Emulsifying properties

The emulsifying properties including EA and ES of the flours and their blends were determined by the methods reported by Beuchat and Neto *et al.* (Beuchat 1977; Neto *et al.* 2001). The flour or the blend of flours (2g) was suspended in distilled water (100 ml) in a measuring cylinder and the height of the suspension (H_1) was noted. The suspension was homogenized with the oil (5 ml) until the formation of emulsion and centrifuged at 1100 rpm for 5 min. The height of the emulsion formed in the cylinder (H_2) was noted and the EA (%) of the flour was calculated by Eq. 2.

$$EA (\%) = (H_2/H_1) \times 100 \quad \dots(2)$$

The emulsion formed by the flour was heated at 80°C for 30 min and centrifuged at 1100 rpm for 5 min. The height of the emulsion (H_3) was noted again and ES (%) of the flour was calculated by Eq. 3.

$$EA (\%) = (H_3/H_2) \times 100 \quad \dots(3)$$

Statistical analysis

The experiments were performed in triplicate and the results were presented as mean $\pm$ standard deviation of three parallel replicates. The variation in the means was analyzed

statistically by one-way analysis of variance (ANOVA). The homogenous subsets of the data were separated by applying the Post-Hock test in Tukey's multiple range tests at 95% confidence level ($p \leq 0.05$) using the statistical software (SPSS, version 19).

RESULTS AND DISCUSSION

The experimental results of EA of the selected flours and their blends are presented in Table 1. The EA of the WF, RWF and MF against the selected cooking oils ranged from 4.47 ± 1.22 to 18.79 ± 2.58 , 7.27 ± 1.82 to 25.46 ± 3.64 and 23.64 ± 2.56 to $29.70 \pm 2.78\%$ respectively. The EA of CPF against the selected cooking oils ranged from 25.46 ± 1.46 to $32.73 \pm 3.64\%$. The EA of the blends of WF, MF, RWF and their combinations with CPF against the selected oils ranged from 9.88 ± 1.08 to $34.57 \pm 2.45\%$.

The experimental results of ES of the selected flours and their blends are presented in Table 2. The ES of the WF, RWF and MF against the selected cooking oils ranged from 91.91 ± 2.18 to 98.65 ± 0.79 , 78.26 ± 1.26 to 93.80 ± 1.24 and 76.64 ± 1.94 to $91.76 \pm 3.81\%$ respectively. The ES of CPF against the selected cooking oils ranged from 80.86 ± 6.55 to $90.22 \pm 4.72\%$. The ES of the blends of WF, MF, RWF and their combinations with CPF against the selected oils ranged from 83.72 ± 2.96 to $98.60 \pm 1.13\%$.

The statistical analysis of experimental data showed a significant difference ($p < 0.05$) in the studied functional properties of the selected cereal flours against each of the selected cooking oils. CPF was found to show the highest EA against corn oil while WF showed the lowest EA against coconut oil. WF showed the highest ES against canola oil and MF possessed the lowest ES against coconut oil. The blending of the cereal flours with legume flour also resulted in significant variation in their emulsifying properties. The blend of WF, MF and CPF exhibited the highest value of EA against sunflower oil and ES against corn oil that were found to be lowest for the blend of MF with CPF against rapeseed oil and RWF with CPF against coconut oil respectively. The EA and ES of wheat and chickpea flours were comparable to those reported earlier (Stone *et al.* 2019). However, the values of EA and ES of pure MF disagreed with those reported earlier (Ishara *et al.* 2018).

The results indicate that the studied emulsifying properties are dependent on the type of the flour as well as the oil. The trends of variation in EA of the blends of flours from those of the respective pure flours against the selected oils are presented in Fig 1a-d. The EA of WF against the selected oils, except corn oil, was increased by 40-640% when blended with CPF and MF. The blend of RWF with MF and CPF also showed a 35-249% increase in EA from that of the pure RWF when tested against the selected oils except for corn oil. The blending of MF with WF, RWF and CPF showed a mixed response of variation in EA from pure MF against different oils. The EA of the blends was found to be decreased by 5-64% against the selected oils except for corn and rapeseed oils where EA was increased by 11-46%

Table 1: Emulsifying activity (%) of flours of different cereals and a legume and their blends using different oils.

	Coconut oil	Canola oil	Corn oil	Rapeseed oil	Sunflower oil	<i>p</i> -value
Flours						
WF*	4.47±1.22 ^{**Bf}	17.75±3.13 ^{Ac***}	18.79±2.58 ^{Ac}	5.39±0.63 ^{Bd}	5.87±1.00 ^{Be}	0.006
RWF	7.27±1.82 ^{Ce}	9.70±2.78 ^{BCd}	25.46±3.64 ^{Ab}	13.94±3.79 ^{Bbc}	8.18±0.91 ^{Cd}	0.003
MF	29.70±2.78 ^{Aa}	24.24±1.05 ^{Bb}	24.24±2.18 ^{Bb}	25.46±1.22 ^{Ba}	23.64±2.56 ^{Bc}	0.020
CPF	25.46±1.46 ^{Bb}	29.70±2.58 ^{ABa}	32.73±3.64 ^{Aa}	26.67±1.05 ^{Ba}	32.12±4.58 ^{Aa}	0.004
Blends						
WF+CPF	11.82±1.91 ^{Cde}	24.85 ±2.78 ^{Bb}	10.30±1.29 ^{Cd}	12.12±2.78 ^{Cc}	29.70±1.05 ^{Aab}	0.000
RWF+CPF	23.02±2.58 ^{Bbc}	29.12±2.58 ^{Aa}	22.42±3.41 ^{Bbc}	12.68±3.14 ^{Cc}	28.55±2.32 ^{Ab}	0.007
MF+CPF	13.76±1.52 ^{Dd}	33.00±3.40 ^{Aa}	21.42±2.07 ^{Bbc}	9.10±2.39 ^{Ec}	29.63±4.91 ^{Aab}	0.000
WF+MF+CPF	33.04±3.48 ^{Aa}	27.59±2.27 ^{Bab}	9.88±1.08 ^{Dcd}	13.51±2.65 ^{Cbc}	34.57±2.45 ^{Aa}	0.001
RWF+MF+CPF	18.84±2.51 ^{Bc}	27.54±4.64 ^{ABa}	11.17±2.64 ^{Cd}	18.81±2.84 ^{Bb}	22.44±2.86 ^{ABc}	0.005
<i>p</i>-value	0.000	0.014	0.008	0.000	0.000	

*WF: Wheat flour, RWF: Refined wheat flour, MF: Maize flour, CPF: Chickpea flour. **The results are expressed as means± standard deviation of three parallel replicates. ***The means differentiated with capital alphabets in each row and those differentiated with small alphabets in each column are statistically different at 95% confidence level ($p \leq 0.05$) using Duncan's multiple range tests.

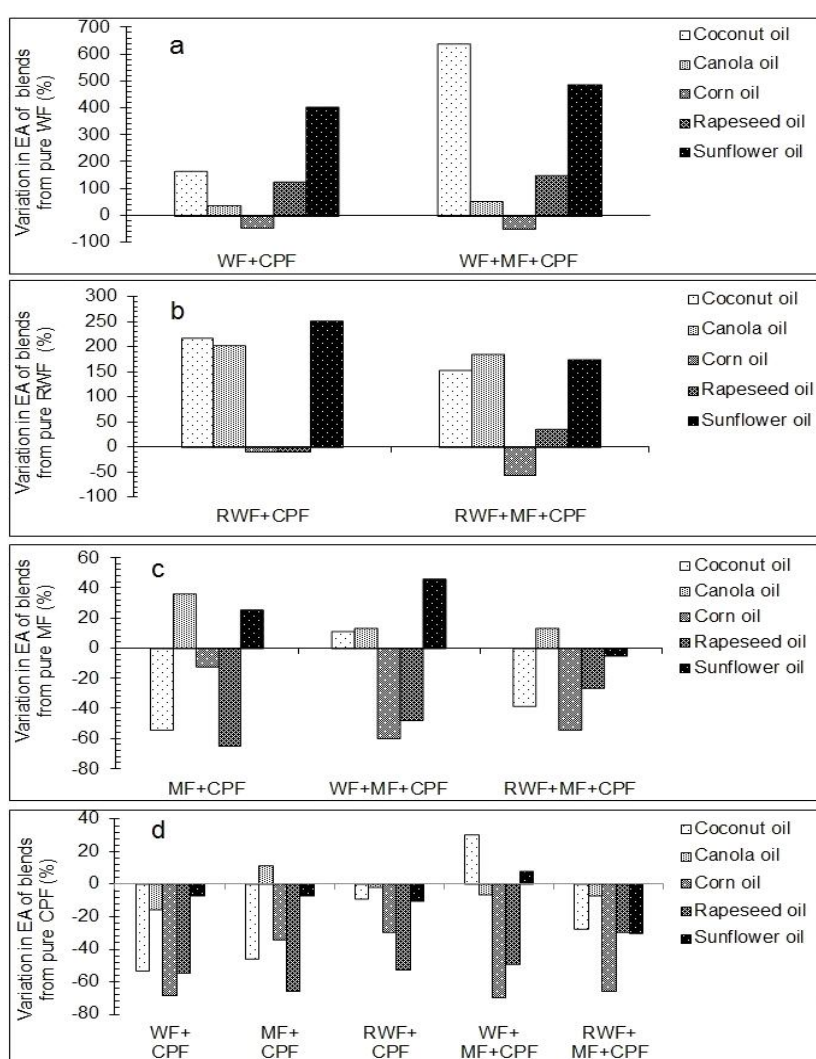


Fig 1: Variation in the emulsifying activity (EA) of the blends of wheat flour (WF), refined wheat flour (RWF) and maize flour (MF) with chickpea flour (CPF) from those of the pure flours in the selected cooking oils.

a) Variation from pure WF, b) Variation from pure RWF, c) Variation from pure MF, d) variation from pure CPF.

as compared to that of pure MF. As compared to the pure CPF, the blends of CPF with the cereal flours showed a 2-70% decrease in EA against the selected oils with few exceptions. The highest increase (640%) in EA was observed in the blend of WF, MF and CPF from that of pure WF against coconut oil. However, the blends of CPF with cereal flours showed a maximum 65-70% decrease in EA as compared to that of the pure CPF against corn oil.

The trends of variation in ES of the blends of flours from those of the respective pure flours against the selected oils are presented in Fig 2a-d. The blends of WF with CPF showed about a 0.75-9% decrease in ES from that of the pure WF against the selected oils. The blend of WF, MF and CPF also showed a 0.51-12% decrease in EA from that of the pure WF against the selected oils except corn oil. The ES of the blend of RWF with CPF was increased by 5-9% from that of the pure RWF against canola, corn and rapeseed oils and

decreased against coconut oil. The blend of RWF, MF and CPF also showed an up to 20% increase in ES from that of the pure RWF against the selected oils except for sunflower oil. The ES of the blends of MF with WF, RWF and CPF was increased by 4-20% from that of the pure MF against the selected oils except for sunflower oil. The blends of CPF with cereal flours showed a 1-17% increase in ES from that of the pure CPF against the selected oils with few exceptions for sunflower oil. The maximum of 20% increase in ES from pure MF was observed in the blend of RWF, MF and CPF against coconut oil while the blend of WF, MF and CPF showed a maximum decrease (12%) in ES from that of pure WF against coconut oil.

As legumes are a richer source of protein and lipids than cereal (Juliano 1999; Stone *et al.* 2019), the variation in emulsifying properties of the blends of cereal flours with CPF from those of the pure flours may be attributed to the

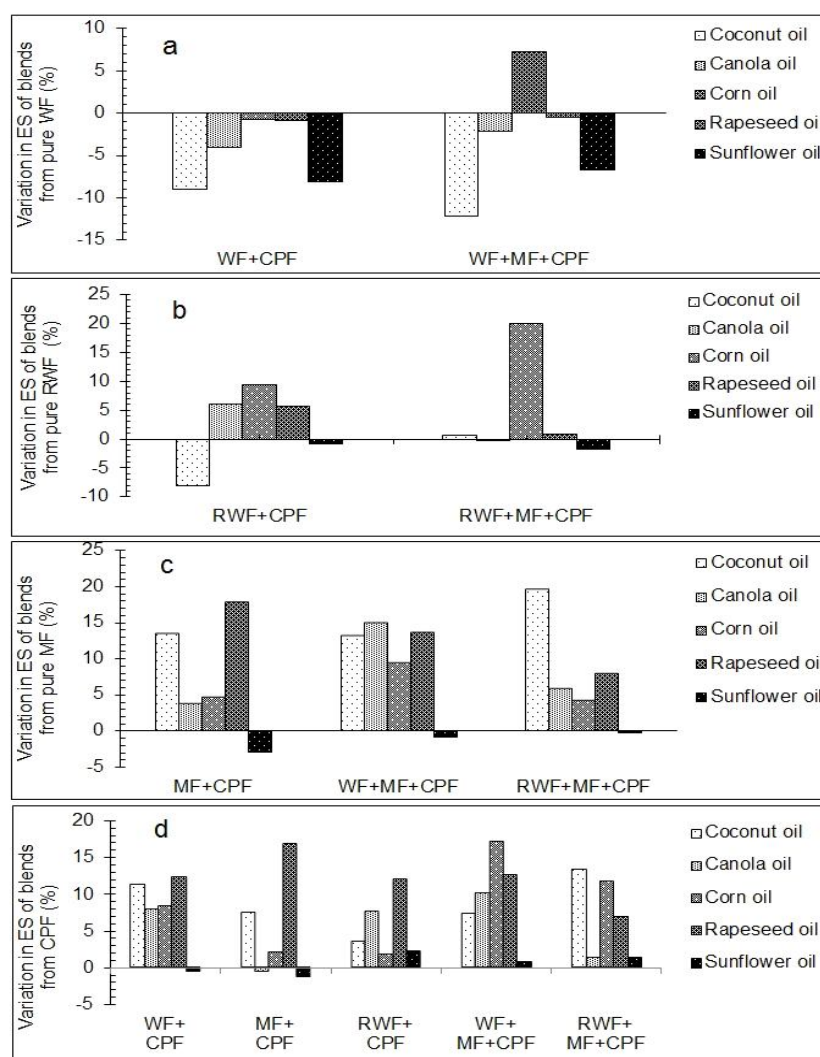


Fig 2: Variation in the emulsifying stability (ES) of the blends of wheat flour (WF), refined wheat flour (RWF) and maize flour (MF) with chickpea flour (CPF) from those of the pure flours in the selected cooking oils.

a) Variation from pure WF, b) Variation from pure RWF, c) Variation from pure MF, d) variation from pure CPF

Table 2: Emulsifying stability (%) of flours of different cereals and a legume and their blends using different oils.

	Coconut oil	Canola Oil	Corn oil	Rapeseed oil	Sunflower oil	p-value
Flours						
WF*	97.79±2.09 ^{**Aa}	98.65±0.79 ^{Aa***}	91.91±2.18 ^{Bbc}	92.65±2.92 ^{Bab}	97.54±1.41 ^{Aa}	0.031
RWF	90.97±0.84 ^{Bb}	89.58±2.02 ^{Bb}	78.26±1.26 ^{Ce}	86.75±2.99 ^{Bb}	93.80±1.24 ^{Ab}	0.047
MF	76.64±1.94 ^{Cd}	84.89±2.96 ^{Bd}	90.14±2.35 ^{Ac}	81.16±1.27 ^{Bc}	91.76±3.81 ^{Abc}	0.004
CPF	80.86±6.55 ^{Bcd}	88.59±2.20 ^{Ac}	84.16±2.70 ^{ABd}	81.85±3.12 ^{Bbc}	90.22±4.72 ^{Abc}	0.013
Blends						
WF+CPF	89.97±0.48 ^{Bb}	95.66±3.15 ^{Aab}	91.22±1.84 ^{ABc}	91.91±1.51 ^{ABab}	89.72±0.72 ^{Bc}	0.025
RWF+CPF	83.72±2.96 ^{Cc}	95.37±1.02 ^{Ab}	85.65±2.99 ^{Ccd}	91.66±1.79 ^{Bab}	92.22±1.46 ^{Bb}	0.001
MF+CPF	86.95±2.02 ^{Bc}	88.10±3.38 ^{ABc}	85.90±1.63 ^{Bcd}	95.36±3.24 ^{Aa}	89.10±1.96 ^{ABc}	0.018
WF+MF+CPF	86.78±1.12 ^{Cc}	97.54±1.58 ^{Aa}	98.60±1.13 ^{Aa}	92.18±3.22 ^{Bab}	90.09±1.56 ^{Bc}	0.024
RWF+MF+CPF	91.63±2.89 ^{ABb}	89.83±1.26 ^{Bc}	94.01±1.92 ^{Ab}	87.56±3.27 ^{Bb}	91.49±1.91 ^{ABbc}	0.007
p-value	0.000	0.002	0.000	0.000	0.026	

*WF: Wheat flour, RWF: Refined wheat flour, MF: Maize flour, CPF: Chickpea flour. **The results are expressed as means± standard deviation of three parallel replicates. ***The means differentiated with capital alphabets in each row and those differentiated with small alphabets in each column are statistically different at 95% confidence level ($p \leq 0.05$) using Duncan's multiple range tests.

changes occurring in the relative protein and lipid profile of the flours. The variation in the type and content of the protein in the flour after blending with the other flour may alter the ability of a particular flour to absorb and retain the maximum quantity of oil (Lin *et al.* 1974). Protein is the major component of the flour which affects its emulsifying properties due to the presence of both hydrophilic and hydrophobic amino acids. The non-polar amino acid side chains can form hydrophobic interaction with the hydrocarbon chains of lipids. On the other hand, the proteins containing a suitable proportion of the polar and nonpolar amino acids exhibit more emulsifying activity and stability (Jitngarmkusol *et al.* 2008; Varsha and Grewal 2014). These properties also depend on the content and type of the lipids present in the flour and the medium.

CONCLUSION

Among the selected cereal and legume flours CPF showed the highest EA against corn oil and WF showed the highest ES against the same oil. The lowest values of EA and ES were observed for WF and MF against coconut oil. The blending of cereal flours with CPF resulted in a mixed response of variation in emulsifying properties as compared to those of the respective pure flours against the selected oils. The EA of the blends was usually found to be increased from those of the pure WF and RWF but decreased from those of the pure MF and CPF against the selected oils with some exceptions. However, the ES of the blends was decreased from that of the pure WF and increased from those of the pure RWF, MF and CPF against the selected oils. The data would help select the suitable combinations of the flours and the oils for the preparation of food products with desirable functional properties.

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REFERENCES

- Akinyede, A.I., Amoo, I.A. (2009). Chemical and functional properties of full fat and defatted Cassia fistula seed flours. *Pak. J. Nutr.* 8(6): 765-9.
- Anton, M., Nau, F., Lechevalier, V. (2009). Egg Proteins. *Handbook of Hydrocolloids*. Elsevier. p. 359-82.
- Arab, E.A., Helmy, I.M.F., Bareh, G.F. (2010). Nutritional evaluation and functional properties of chickpea (*Cicer arietinum* L.) flour and the improvement of spaghetti produced from its. *Journal of American Science*. 6(10): 1055-1072.
- Badar, H. (2013). Functional properties of maize flour and its blends with wheat flour: Optimization of preparation conditions by response surface methodology. *Pak. J. Bot.* 45(6): 2027-35.
- Bajaj, R., Singh, N., Kaur, A., Inouchi, N. (2018). Structural, morphological, functional and digestibility properties of starches from cereals, tubers and legumes: A comparative study. *Journal of Food Science and Technology*. Springer, 55(9): 3799-808.
- Beuchat, L.R. (1977). Functional and electrophoretic characteristics of succinylated peanut flour protein. *Journal of Agricultural and Food Chemistry*. 25(2): 258-61.
- Bushuk, W. (1986). Wheat: Chemistry and Uses. *Cereal Foods World* (USA).
- Chau, C.F., Cheung, P.C.K. (1998). Functional properties of flours prepared from three Chinese indigenous legume seeds. *Food Chemistry*. 61(4): 429-33.
- Edema, M.O., Sanni, L.O., Sanni, A.I. (2005). Evaluation of maize-soybean flour blends for sour maize bread production in Nigeria. *African Journal of Biotechnology* [Internet]. [cited 2016 Feb 1];4(9). Available from: <http://www.ajol.info/index.php/ajb/article/view/71122>.
- Farooq, Z., Boye, J.I. (2011). Novel food and industrial applications of pulse flours and fractions. *Pulse foods: Processing, quality and nutraceutical applications*. Elsevier: Amsterdam, The Netherlands. 283-323.

- Fasasi, O.S., Adeyemi, I.A., Fagbenro, O.A. (2006). Physicochemical properties of Maize-tilapia flour blends. *Journal of Food Technology*. 2(3): 342-5.
- Feng, H., Jin, H., Gao, Y., Yan, S., Zhang, Y., Zhao, Q., *et al.* (2020). Effects of freeze-thaw cycles on the structure and emulsifying properties of peanut protein isolates. *Food Chemistry*. Elsevier. 330: 127215.
- Hussain, A., Kaul, R., Bhat, A. (2018). Development of healthy multigrain biscuits from buckwheat-barley composite flours. *Asian Journal of Dairy and Food Research*. 37(2): 120-5.
- Ishara, J.R., Sila, D.N., Kenji, G.M., Buzera, A.K. (2018). Nutritional and functional properties of mushroom (*Agaricus bisporus* and *Pleurotus ostreatus*) and their blends with maize flour. *American Journal of Food Science and Technology*. 6(1): 33-41.
- Jitngarmkusol, S., Hongsuwankul, J., Tananuwig, K. (2008). Chemical compositions, functional properties and micro-structure of defatted macadamia flours. *Food Chemistry*. 110(1): 23-30.
- Juliano, B.O. (1999). Comparative nutritive value of various staple foods. *Food Reviews International*. Taylor and Francis. 15(4): 399-434.
- Kaur, G.J., Rehal, J., Singh, A.K., Singh, B., Kaur, A. (2014). Optimization of extrusion parameters for development of ready-to-eat breakfast cereal using RSM. *Asian Journal of Dairy and Food Research*. 33(2): 77-86.
- Kim, W., Wang, Y., Selomulya, C. (2020). Dairy and plant proteins as natural food emulsifiers. *Trends in Food Science and Technology*. Elsevier.
- Lin, M.J.-Y., Humbert, E.S., Sosulski, F.W. (1974). Certain functional properties of sunflower meal products. *Journal of Food Science*. 39(2): 368-70.
- Nawaz, H., Muzaffar, S., Aslam, M., Ahmad, S. (2018). Phytochemical Composition: Antioxidant Potential and Biological Activities of Corn. *Corn-Production and Human Health in Changing Climate*. IntechOpen.
- Nawaz, H., Shad, M.A., Mehmood, R., Rehman, T., Munir, H. (2015). Comparative evaluation of functional properties of some commonly used cereal and legume flours and their blends. *International Journal of Food and Allied Sciences*. 1(2): 67-73.
- Neto, V.Q., Narain, N., Silva, J.B., Bora, P.S. (2001). Functional properties of raw and heat processed cashew nut (*Anacardium occidentale* L.) kernel protein isolates. *Food/Nahrung*. 45(4): 258-62.
- Pomeranz, Y. (2012). *Functional Properties of Food Components*. Academic Press.
- Qamar, S., Manrique, Y.J., Parekh, H., Falconer, J.R. (2020). Nuts, cereals, seeds and legumes proteins derived emulsifiers as a source of plant protein beverages: A review. *Critical reviews in food science and nutrition*. Taylor and Francis. 60(16): 2742-62.
- Shad, M.A., Nawaz, H., Hussain, M., Yousuf, B. (2011). Proximate composition and functional properties of rhizomes of lotus (*Nelumbo nucifera*) from Punjab, Pakistan. *Pak. J. Bot.* 43(2): 895-904.
- Stone, A.K., Nosworthy, M.G., Chiremba, C., House, J.D., Nickerson, M.T. (2019). A comparative study of the functionality and protein quality of a variety of legume and cereal flours. *Cereal Chemistry*. Wiley Online Library. 96(6):1159-69.
- Tanwar, B., Lamsal, N., Goyal, A., Kumar, V. (2019). Functional and physicochemical characteristics of raw, roasted and germinated buckwheat flour. *Asian Journal of Dairy and Food Research*. 38(2): 140-144.
- Varsha, R., Grewal, R.B. (2014). Physical and functional properties of six varieties of lentil (*Lens culinaris* Medik.). *Asian Journal of Dairy and Food Research*. 33(2): 126-30.
- Wu, H., Wang, Q., Ma, T., Ren, J. (2009). Comparative studies on the functional properties of various protein concentrate preparations of peanut protein. *Food Research International*. 42(3): 343-8.
- Zeng, J., Gao, H., Li, G., Liang, X. (2011). Extruded corn flour changed the functionality behaviour of blends. *Czech Journal of Food Sciences*. 29(5): 520-7.