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Research Article

Estimation of Roasted and Raw Faba Bean and Lentil Flour Functional Properties

Kristine Ozolina[1*], Inga Sarenkova[1, 2], Sandra Muizniece-Brasava[1, 3]

[1]Faculty of Food Technology, Latvia University of Life Sciences and Technologies, 22a Rigas Street, Jelgava, Latvia

[2]Institute of Agricultural Resources and Economics, 2 Zinatnes Str., Priekuli, Priekuli Parish, Cesis Municipality, LV- 4126, Latvia;

[3]Technology and knowledge centre at Latvia University of Life Sciences and Technologies. 22b Rigas Street, Jelgava, Latvia.

[*]**Corresponding author**: Kristine Ozolina, Faculty of Food Technology, Latvia University of Life Sciences and Technologies, 22a Rigas Street, Jelgava, Latvia

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Abstract

The use of legumes in Latvia is increasing, because they contain abundant proteins, so it is important to provide high-quality and safe of legume products. Many of the treatment processes performed to carry off, that legumes for the human organism are eventually digestible and free of anti-nutritional factors. Roasting is an important method for processing legume flour from raw into an eatable product. Overall, roasting is operated to process cooked food products and convert the composition of phenolic compounds in legumes, and as a result, gain products from legumes with pleasant quality sensory. This study compared raw and roasted faba bean and lentil flours. Different properties of flours were determined such as water absorption capacity, moisture, density, oil absorption capacity, swelling capacity, colour analysis, foam capacity, foam stability, emulsion activity, emulsion stability, gelatinization temperature, and least gelation concentration. The study showed that roasted flour is significantly more valuable for improving functional properties than raw flour. Roasted flour has a darker shade by colour analysis. According to the research results, it can be concluded that it is more valuable to use roasted flour in the production of food products.

Keywords: Legumes; Plant-Based; Roasting-Drying; Flour

Introduction

The requirement to plant based proteins is rapidly increasing with growing awareness of the carbon footmark induced by meat and dairy based foods, since plant based foods have less carbon footmarks. Legumes are in the spotlight among all plant based protein sources and play a significant function in human nutrition for their high composition of protein, starch, minerals, vitamins, and carbohydrates, including dietary fibre. Roasting legumes effectively enhances functional food performance by improving the final product quality of the sensory, like aroma, flavor, nutraceutical content and changes the composition of phenolic compounds in legumes [1-3]. The usage of the roasting method has more advantages, like high roasting capacity, advanced product quality, less environmental and also roasting is used to improve the texture, functional and organoleptic properties, and storage time of legumes. Overall, roasting treatment is a successful alternative treatment for utilizing legumes as a snack [4].

Flour of legumes are gain by milling them and is mostly used in bakery and in other cooking products [3]. Functional properties are the major physicochemical characteristics of flour and they represent the composition, complex interactions among the structure, and the behavior of compounds during cooking and also the preparation process [5]. Particle size of legumes flour is also known as granularity and is a quality control parameter after the milling process. The particle size is usually measured by geometric methods, by sieving a representative amount of sample [6]. Smaller size legume flours provide a complete, homogeneous, and practically instant hydration of the protein macromolecules essential for the formation and development of the dough. If the flour particle's size is coarser, then will be longer the mixing time, accordingly increase the power consumption of mixing [7]. Water and oil absorption are greatly dependent on the grinding size of the flour used. The finer grinding size of flour gives better quality of bread and other cooking products. In contrast, excessively coarse flours produce low-quality cooking products, since dough hydration is limited and takes longer to complete [8]. Water absorption of wheat flour is one of the most important legumes flour quality characteristics since it provides guidance for determining baking absorption and relates closely to the yield and quality of bakery products [9].

Estimating different functional properties of raw and roasted faba bean and lentil flours with different particular size are the focus of the current study.

Materials and Methods

The research was managed in the scientific laboratory and laboratory of microbiology in the Faculty of Food Technology, Latvia University of Life Science and Technology, Jelgava, Latvia. Both raw and roasted materials: lentil (*L. culinaris*) flour and faba bean (*L. Vicia faba*) flour were received from the local manufacturer Ltd "ZEKANTS" (Latvia) for the present study.

Functional properties of flours

Four individual samples: raw faba bean, raw lentil, roasted faba bean, and roasted lentil flour were sifted manually through a sieve and divided into samples of different particle sizes shown in Table 1.

Sample Code	Description of the sample
L1	Raw lentil flour with a grind of 0.71 to 1.00 mm
L2	Raw lentil flour with a grind of < 0.71 mm
RL1	Roasted lentil flour with a grind of 0.71 to 1.00 mm
RL2	Roasted lentil flour with a grind of < 0.71 mm
B1	Raw faba bean flour with a grind of 0.71 to 1.00 mm
B2	Raw faba bean flour with a grind < 0.71 mm
RB1	Roasted faba bean flour with a grind of 0.71 to 1.00 mm
RB2	Roasted faba bean flour with a grind of < 0.71 mm

Table 1: Sample characteristics.

All flour samples were stored in woven polypropylene bags at ambient temperature 20± 2 ˚C. All flour samples were analyzed with different functional properties:

- **Water absorption** – water absorption was determined by using a centrifuge. In the procedure, 1 g of flour was mixed with 10 mL distilled water at room temperature 20 ± 2 ˚C and allowed to stand for 30 min. Samples were centrifuged for 10 min at 5000 rpm. Centrifugation separates the components of the mixture according to Stokes equation, that centrifugation depends of particle density, diameter and size; thus this purification step is important process to separate the flour form excess water. Water absorption was examined as the percent water bound per 1 gram of flour sample [10].
- **Oil absorption** – oil absorption capacity is determined as the amount of oil absorbed by the flour. 1 g of flour sample was mixed with 10 mL canola oil (Specific gravity at 25 ˚C: 0.916) in a centrifuge tube and allowed to stand for 30 min at ambient temperature 20±2 ˚C. Tubes were then centrifuged for 10 min at 5000 rpm. This purification step is important process to separate the flour form excess oil. Oil absorption was expressed as the percent of oil bound per gram of flour sample [11].
- **Density** - The flour sample was weighed 100 g and applied into a measuring cylinder of 200 mL. The cylinder was tapped on a timbered board until was noticed no visible decrease in volume. The apparent (bulk) density was calculated based on the weight and volume of flours [12].
- **Swelling capacity** – 10 mL of the sample was transferred into a graduated 100 mL cylinder. Distilled water was added to give a total volume of 50 mL. The graduated cylinder was covered with a cap and mixed by reversing the cylinder. The sample was mixed again after 5 min and left to stand for a more 10 min. and then the swelling capacity was determined by directly reading the volume of the swollen sample in the cylinder [13].
- **Foam capacity** – The 10 g flour sample was added to 50 mL distilled water at 25 ± 2 °C in a graduated cylinder. The sample was mixed and shaken for 10 min to foam. The volume of foam at 30 s after whipping. Foaming capacity was assessed according to the following equation, where V_1 – sample volume before shaking; V_2 – sample volume (including foams) after shaking [14]:

$$Foam\ capacity\ (\%) = \frac{V_1 - V_2}{V_1} \times 100 \qquad (1)$$

- **Foam stability** - The 10 g flour sample was added to 50 mL distilled water at 25 ± 2 ˚C in a graduated cylinder. The sample was mixed and shaken for 10 min to foam. The volume of foam was recorded 120 min after whipping to determine foam stability as per percent of initial foam volume, where V_2 – sample volume (including foams) after shaking; FV_1 – Foam volume directly after shaking; FV_2 – Foam volume after 120 min left rest [14]:

$$Foam\ stability\ (\%) = \frac{FV_2}{FV_1} \qquad (2)$$

- **Emulsion activity** – 1 g flour and 10 mL distilled water in a calibrated centrifuge test tube were mixed, followed by the addition of 10 mL canola oil. The sample was mixed for 10 min by vigorous shaking. The resulting emulsion was centrifuged at 5000 rpm for 30 min. The ratio of the height of the emulsion layer to the height of the liquid layer was calculated, and the emulsion activity was expressed in percentage [15].
- **Emulsion stability** – 1 g flour and 10 mL distilled water in a calibrated centrifuge test tube were mixed, followed by the addition of 10 mL canola oil. The sample was mixed for 10 min by vigorous shaking. The emulsion stability was determined after heating the emulsion at 80 ˚C for 30 min in a water bath. After that cooling to an ambient temperature of 20 ± 2 ˚C and centrifuging at 5000 rpm for 10 min. Expressed as a percentage, was calculated as the ratio of the height of the emulsified layer to the height of the liquid layer [15].
- **Least gelation concentration** - The flour sample of 4, 8, 10, 12, 14, 16, 18, 20, 24, 28 and 32 % (w/v) were mixed in 10 mL distilled water and were heated at 90 ˚C for 60 min in a water bath. The suspension was cooled in an ambient temperature water bath of 20±2 ˚C and kept for 3 h at 8±1 ˚C. The least gelation concentration was set in the experiment given as that concentration when the sample did not slip out after the tube was turned upside down [16].
- **Gelatinization temperature** – 1 g of flour was transferred to 20 mL screw-capped tubes. 10 mL of distilled water was applied to each sample. The samples were heated to 90 ˚C and then slowly cooled in a water bath until they formed a gel. At stable gel formation, the appropriate temperature was estimated and assumed as gelatinization temperature [16].

Analytical methods

- **Moisture content** - the amount of water in a 1 g sample was determined by moisture analyzer Precisa Gravimetrics AG, CH-Dietikon, Switzerland, and expressed as a percentage of weight.
- **Colour analysis** – was determined to solid 10 g of analysed product. Colour analysis was performed using L*a*b* coordinates defined by the International Commission on Illumination with "ColorFlex EZ Spectrophotometer" (HunterLab, USA) colour analyser. Colour analyser was calibrated for colour intensity analyses. The samples were added into equal weight in transparent container and placed at the analyser sensor. The lid was closed above the containers so that ambient light had no effect on the colour of the samples. Results are expressed as the mean±standard deviation of seven experiments.

$$\Delta E_{ab} = \sqrt{(L_2 - L_1)^2 + (a_2 - a_1)^2 + (b_2 - b_1)^2} \qquad (3)$$

where:

L2, a2, b2 – colour of the roasted flour sample;

L1, a1, b1 - colour of raw flour sample.

Color analyser showed that a negative a* value indicates the intensity of the green colour, a positive value of a* indicates the intensity of the red colour, a negative value of b* indicates the intensity of the blue colour, a positive value of b* indicates the intensity of the yellow colour, and L* is an indicator of white and black or light and dark intensity. The total colour intensity difference – ΔE_{ab} was calculated by comparing the colour of the roasted flour product with the colour of raw flour product. The given formula calculates the difference between the two colours to identify inconsistencies [17, 18].

- Product visual assessment was recorded right after milling process and picture placed in 1. Figure.

Stastistical analysis

Data acquisition and analysis were performed with Microsoft Office Excel v16.0. Results are expressed as the mean±standard deviation of three experiments unless specified otherwise. Data acquisition and analysis were performed with the variance analysis method ANOVA, and a t-test was performed. A p value lower than 0.05 ($P<0.05$) was considered significantly different.

Results

The visual appearance of the samples differed since the flour samples differed: in composition - bean and lentil; in grind size - of < 0.71 mm and of 0.71 to 1.00 mm; and in the type of processing - raw and roasted. The visual appearance of the bean and lentil flour samples shown in 1. Figure where sample code (from Table 1.) is added next to the relevant flour sample.

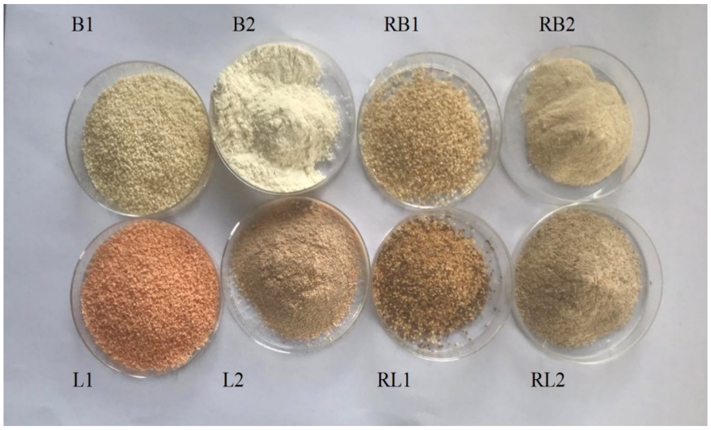


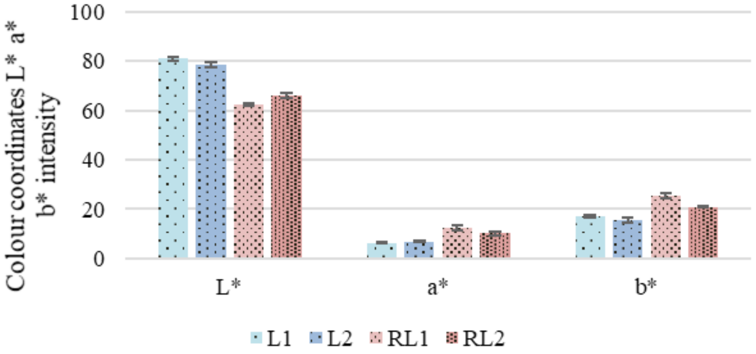
Figure 1. The visual appearance of the raw and roasted bean and lentil flour samples with different particle size.

In Figure 1. can notice obvious color changes among raw and roasted flour samples and among samples with different particle sizes. It is clearly visible, that roasted samples are darker than raw flour samples. It can also be observed between samples that the flour appears grainier in samples with coarser flour particle sizes. A color difference is also observed between lentil and faba bean flour. Lentil flour has a red hue and is slightly darker compared to faba bean flour. In order to see more clearly the color difference between the lentil and faba bean flour samples, a color analysis was performed.

Results of colour analysis

Roasted legumes are obtained by high heat drying process and it affects the legume color changes during roasting [1], thus the obtained colour of roasted legume flour samples was compared with the raw legume flour samples. The colour of the product gives a hint of how clean the product is of impurities that influence the colour. Figure 2. shows a comparison of colour intensities among lentil and faba bean flour samples.

(a)



(b)

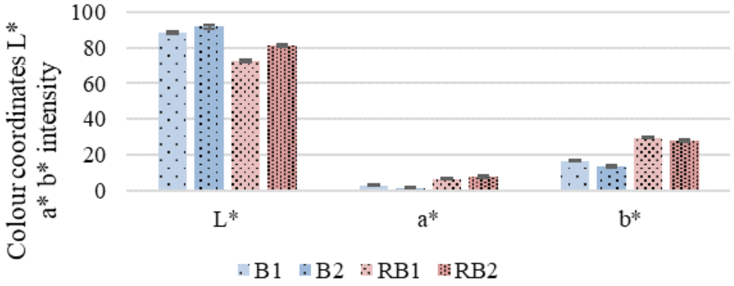


Figure 2. Results of color analysis of L* coordination of white-black color, a* coordination of red-green color, b* coordination of yellow-blue color in **(a)** lentil flour samples; **(b)** faba bean flour samples.

In Figure 2 (a) it can be observed that raw lentil flour samples L1 and L2 are lighter than roasted lentil flour samples RL1 and RL2 ($p < 0.05$). In Figure 2 (b) can be observed same that raw faba bean flour samples B1 and B2 are lighter than roasted faba bean flour samples RB1 and RB2 ($p < 0.05$). Faba bean samples are with darker hue than lentil flour samples ($p < 0.05$). All roasted lentil and faba bean flour samples have a higher red and yellow colour intensity compared to the raw lentil and faba bean samples ($p < 0.05$). Colour analysis shows that roasting process change raw flour colour into darker colour and with more red and yellow colour hue. The lightest sample was observed to be raw faba bean flour (sample B2) with L * value of 91.81, it is very similar to the obtained wheat flour L* value of 92.65 in another research [19].

Established differences are significant ($p < 0.05$) among raw and roasted flour samples in all colour L*a*b* system coordinate intensions. Roasting process gives out a darker flour product. Bai et al. [20] found that roasting grows antioxidant activity due to the Maillard reaction product formation and a decrease in the total phenolic content. Maillard reaction products are omnipresent in heat-processed foods, involving reducing sugars and amino compounds. The high roasting temperature affects the formation of Maillard reaction products, such as melanoidin's, the Maillard reaction final products [1]. Lentil and faba bean are rich in proteins and this component is a major index for the Maillard reaction, thus roasted flour samples are darker and have more pronounced red and yellow color hue than raw flour samples because in the roasting process lentil and faba bean were treated by heat and due that formatting Maillard reaction products [1, 21].

Assessments of lentil and faba bean flour samples functional properties

Lentil and faba bean flour samples moisture, swelling capacity, oil and water absorption, density, total colour intensity, emulsion activity and stability, foam capacity and stability, gelatinization temperature and least gelation concentration differences were determined (Table 2 and 3) to compare raw flour samples with roasted flour samples.

	Moisture, %	**Swelling capacity, ml**	**Oil absorption, %**	**Water absorption, %**	**Density, g cc^{-1}**	**The total colour intensity difference, ΔE_{ab}**
L1	7.47 ± 0.45^{a}	10.50 ± 1.00^{a}	142.92 ± 2.45^{a}	186.10 ± 2.35^{a}	0.79 ± 0.11^{a}	-
L2	7.79 ± 0.32^{a}	19.00 ± 1.50^{b}	135.32 ± 1.20^{b}	270.58 ± 0.55^{b}	0.76 ± 0.09^{ab}	-
RL1	5.98 ± 0.12^{b}	17.50 ± 2.00^{bd}	164.24 ± 3.65^{c}	357.43 ± 4.45^{c}	0.74 ± 0.06^{a}	20.87 ± 0.82^{a}
RL2	6.12 ± 0.60^{c}	28.00 ± 2.00^{c}	161.89 ± 1.23^{c}	336.58 ± 1.21^{d}	0.75 ± 0.12^{abc}	14.12 ± 0.88^{b}
B1	8.53 ± 0.41^{d}	10.50 ± 0.50^{a}	159.54 ± 2.10^{c}	152.07 ± 1.05^{e}	0.59 ± 0.08^{bc}	-
B2	8.74 ± 0.11^{d}	12.00 ± 0.50^{d}	146.77 ± 0.89^{a}	229.32 ± 3.09^{f}	0.60 ± 0.07^{bc}	-
RB1	4.31 ± 0.32^{e}	14.50 ± 1.50^{e}	182.24 ± 2.21^{d}	322.90 ± 4.24^{g}	0.57 ± 0.10^{bc}	20.72 ± 0.85^{a}
RB2	4.41 ± 0.33^{e}	17.00 ± 2.00^{be}	187.33 ± 1.05^{e}	306.13 ± 2.87^{h}	0.57 ± 0.07^{c}	19.28 ± 0.57^{c}

Different superscripts within a column (a, b, c, d, e, f, g, h) are significantly different ($p < 0.05$).

Table 2. Lentil and faba bean flour samples moisture, swelling capacity, oil and water absorption, density and total color intensity difference.

Based on the gained results (Table 2) roasting significantly decreases the moisture content and swelling capacity in roasted flour samples compared to the raw flour sample ($p < 0.05$). It is significant to examine the moisture content of flours due to their influence on physicochemical and microbiological properties. Moisture content also gives an impact on the agglomeration, flow behaviour, and compression of powdered products [22]. Results showed that swelling capacity was significantly different ($p < 0.05$) among samples with different lentil and faba bean flour particle sizes, thus finer flour swells more in water than coarse flour.

As can be noticed in the results roasted lentil and faba bean flour samples have significantly ($p < 0.05$) higher water and oil absorption capacity compared to raw lentil and faba bean flour samples. The usage of roasting treatment on lentil and faba bean flour have a beneficial effect on the amount of water and oil absorption. As well, there are only a few researches that have examined the contribution of all the main aspects commonly recognized to promote water and oil absorption, i.e. legumes flour damaged starch and hardness, protein, and pentosans content [9]. The adsorption takes place on the inner walls of the pore particles [23]. Perhaps it is because, in the roasting process, the proteins denaturates, and the exposure of more polar amino acids to oil and water increases [5]. Due to the essential role of water-holding extent in dough and cooked products, higher water absorption would improve the characteristics and freshness of the food product [9]. The oil absorption capacity is an important factor in food formulations as it enriches the flavor and improves the mouth feel of foods [19].

The lentil and faba bean flour bulk density is the density estimated without the impact of any compression and it depends on the initial moisture content and flour particle size [16]. There were no significant differences on density between raw and roasted flour samples. The results also showed that there was no difference in density between samples with different particle sizes. The particle size of flour and the treatment method of raw or roasted flour did not influence the density of samples. Lentil flour sample has a higher density of 0.74 - 0.79 g cc^{-1} than faba bean flour samples of 0.57 - 0.60 g cc^{-1}. Chandra et al., was determined, that wheat flour has a density of 0.76 g cc^{-1} [16], which is similar to lentil flour samples.

ΔE_{ab} calculation of the total colour intensity difference shows how close is roasted flour sample colour to raw flour sample colour. Calculated colour intensity difference was from 14.12 – 20.87 ΔE_{ab}, this proves that the roasting process affects the colour of the lentil and faba bean flour.

Results showed roasting significantly increased the oil absorption capacity, swelling capacity, water absorption capacity, and colour exchanges into darker hue and decreased moisture content of lentil and faba bean flours.

	Emulsion activity, %	Emulsion stability, %	Foam capacity, %	Foam stability, %	Gelatinization temperature, °C	Least gelation concentration, %
L1	40.90 ± 3.33^{a}	18.18 ± 2.80^{ad}	44.50 ± 0.55^{a}	86.36 ± 0.75^{a}	-	-
L2	40.90 ± 3.50^{a}	22.22 ± 2.50^{ac}	49.85 ± 0.90^{b}	93.87 ± 0.89^{b}	36.45 ± 0.67^{a}	12^{a}
RL1	40.90 ± 3.95^{a}	95.00 ± 3.45^{be}	7.50 ± 0.45^{c}	57.12 ± 1.28^{c}	-	-
RL2	40.90 ± 3.45^{a}	96.50 ± 2.33^{b}	17.50 ± 0.50^{d}	57.14 ± 1.56^{c}	45.22 ± 0.15^{b}	8^{b}
B1	45.45 ± 3.50^{a}	22.22 ± 1.45^{c}	40.00 ± 1.50^{e}	66.67 ± 0.85^{d}	-	-
B2	40.90 ± 3.00^{a}	15.05 ± 3.75^{d}	44.75 ± 0.45^{a}	70.45 ± 0.79^{e}	38.98 ± 1.45^{c}	16^{c}
RB1	45.45 ± 3.85^{a}	90.50 ± 2.25^{e}	10.35 ± 0.20^{f}	40.00 ± 2.33^{f}	-	-
RB2	45.45 ± 3.00^{a}	95.00 ± 1.60^{b}	17.25 ± 0.55^{d}	65.71 ± 0.95^{d}	48.35 ± 0.89^{d}	12^{a}

Different superscripts within a column (a, b, c, d, e, f) are significantly different ($p < 0.05$).

Table 3: Lentil and faba bean flour samples emulsion activity and stability, foam capacity and stability, gelatinization temperature and least gelation concentration differences.

Results showed no significant differences ($p > 0.05$) in emulsion activity among all samples. But in emulsion stability, there was a significant difference ($p < 0.05$) between roasted flour samples and raw flour samples. Emulsion stability was obviously higher in roasted flour samples, while the emulsion was unstable in raw flour samples. Interestingly is that the reverse situation was observed in foam capacity and stability, there raw flour samples have significantly higher ($p < 0.05$) forming foam capacity, while roasted flour samples scarcely foamed, and also foam stability was observed less than in raw flour samples. The foaming capacity of raw wheat flour was found to be only 30.40% [19], while in this study raw lentil and faba bean flour foaming capacity reach 40.00 - 49.85%. Flour foaming depends on protein and carbohydrate content [24]. The higher foaming and stability of foams are due to the attendance of a higher quantity of solubilized native protein in the flour. The foaming capacity of the lentil and faba bean flour relies on the presence of flexible protein molecules that can reduce the surface tension of water. Foaming capacity is significant in the preservation of the structure and texture of food products like bakery and ice cream [19].

The ability of proteins from lentil and faba bean flour to form gels was measured by the least gelation concentration and also determined the highest temperature of gelatinization. The obtained results showed that the roasted flour samples require a lower concentration when they start to form a gel consistency. Raw lentil flour dissolved in distilled water gelates at 12% of concentration, while roasted lentil flour gelates at 8% of concentration. The same was with raw faba bean flour and roasted faba bean flour dissolved in distilled water, they gelate 16% and 12 % of concentration, respectively. Slowly cooling high temperature was found that the gelatinization temperature in which the sample starts to gelate was estimated to be significantly higher ($p < 0.05$) in roasted flour samples compared to raw flour samples. The lentil and faba bean roasted flours instead of raw flour would be more useful in food systems like puddings, different deserts, sauces, and other products which require gelling and thickening. The variation in the gelling capacity can be referred to as the proportion of the different components such as protein, carbohydrates, and lipids in different legume flours, suggesting that interaction between those compounds may also have an important role in functional properties [25].

Besides, the starch gelatinization, raw fiber swelling, mucilage during the heat treatment in the roasting process also increase water absorption capacity considering hydrophilic portions like charged or polar side chains [5].

Conclusions

According to the study results, it may be concluded that it is more valuable to utilize roasted flour instead of raw flour in the production of food products because the results proved that roasting improves the functional properties of lentil and faba bean flour, such as water and oil absorption capacity, swelling capacity, emulsion stability, and also more advanced to forming gelation. Only foam capacity and stability was less effective with roasted flour samples, while it was successful with raw flour samples. Roasted flour samples has a darker shade by colour analysis because roasting has affected sample components. The research showed that roasted lentil and faba beam flour are significantly more valuable for improving functional properties than raw flour.

Disclosure

Author Contributions: Conceptualization, K.O., I.S. and S.M-B..; methodology, K.O. and I.S.; software, K.O. and I.S.; validation, K.O. and S.M-B. investigation, K.O. and I.S.; resources, K.O., I.S. and S.M-B.; data curation, K.O. and I.S.; writing—original draft preparation, I.S..; writing—review and editing, K.O., I.S. and S.M-B.; visualization, I.S. and S.M-B..; supervision, I.S. and S.M-B..; project administration, K.O.; funding acquisition, K.O. and S.M-B. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement: The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Conflicts of Interest: The authors declare no conflict of interest.

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