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Effects of Blending Ratio and Lupine Variety on the Functional Properties of Composite Flours and Sensory Evaluations of Tef-Lupine Injera

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Abstract
This study was conducted to investigate the effect of lupine flour on functional properties and sensory acceptability of tef-lupine blended injera. Injera is a staple food for Ethiopian and it is fermented, sour leavened pancake-like bread made from blending of different cereals like tef, barley, sorghum, maize and wheat. Besides, there are limited studies on formulating of injera from composite flour with legumes (lupine). The effect of two factors two lupine varieties (Australian sweet lupine and Dibettered lupine seed) and blending ratios (0, 2.5, 5, 7.5, 10, 15, 17.5 and 20). Maximum and minimum levels of independent variables were first investigated by doing a preliminary analysis and founded that tef from up to80-100% and lupines from up to 0-20%. Response surface methodology was applied to find the formulations and predictive model. Sensory acceptance of tef-lupine injera was affected by interaction of varieties and blending ratios. Oil absorption capacity and swelling power properties of composite flour decrease as blending ratio of lupines increased and water absorption and foaming capacity increased as blending ratio of lupines increases for both varieties. As the sensory acceptability scores data indicated for both lupine varieties blended with tef for the production of injeras of up to 15% lupines almost all sensory attributes showed higher scores without significantly different among them but after 15% lupine addition there were observed drop of the sensory acceptability scores. In a 7 point hedonic scale, the composite sample tef injeras with 10% dibettered lupine seed variety addition had the highest scores of 6.09, 6.22, 6.09 and 6.18 in eye size, aroma, rollability and overall acceptability respectively. The L* value and number of eye by injera eye software were 72.77 to 79.84 and 14220.43 to 18929.33, respectively. The L values of blended injera increased as lupine proportion were increased, but the number of injeras eyes decreased.
Keywords: Dibettered lupine seed, Composite injera, Response surface methodology
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INTRODUCTION

Injera is fermented, sour leavened, pancake-like, moist, chewy and elastic bread made principally from *tef* (*Eragrostis tef (Zucc.) Trotter*). But it can also make from other cereals like wheat, barley, sorghum or maize or a combination of some of these cereals. *Injera* most importantly consumed in Ethiopia and Eritrea, but it is now adapted i the world. It is served in restaurants in Europe, North America, and Israel and is receiving an enthusiastic acceptance (NRC, 1996). *Injera* from *tef* is most preferred due to its softer texture, preferred taste, its colour, and can be rolled without cracking. However, it is more widely consumed by the economically better off urban peoples than by rural households (Assefa *et al.,* 2015 and Bemertu *et al.,* 2013). So for rural households and the urban poor, *tef* is more of a luxury while maize, wheat and rice are necessity food grains. As *tef* prices go up, even middle income households tend to mix *tef* flour with cheaper cereals such as sorghum maize or rice in preparing *injera* (Demeke and Marcantonio, 2013).

Tef (Eragrostis tef (Zucc) Trotter) is an important staple cereal crop in Ethiopia. It is cultivated as a major cereal in Ethiopia and represents 19% of the total cereal production, with the largest share area (23.42%, about 2.6 million hectares) under cereal cultivation (CSA, 2017). Its grain is mainly used for making different kinds of *injera*. It has similar protein content to other more common cereals like wheat, but contains no gluten. *Tef* amino acid composition is well-balanced and contains relatively higher concentrations of lysine than what is commonly found in other cereals. The amino acid composition of grain *tef* is comparable to that of egg protein, except for its lower lysine content.

Lupines can be divided into sweet lupines, which contain low levels of alkaloids, and bitter lupines, which contain higher levels of alkaloids. Lupine generally contains about twice the amount of proteins found in those legumes that are commonly consumed by humans. Lupine is a good source of nutrients, not only proteins but also lipids, dietary fibre, minerals, and vitamins (Martinez-Villaluenga *et al.,* 2009). Lupine flour has high nutritional value containing about (33-47%) protein, (20-30%) dietary fibre and (6-13%) fat contents and has low glycaemic index (GI) due to little or no starch content.

It is common in Ethiopia injera were prepared from *tef* mixed with different cereals like sorghum, barley, wheat, millet, maize, rice or wheat which has protein content of ranges from 8-15% (Ashenafi, 2006), but blending of *tef* with lupine are not yet practiced in our country even if it have higher amount of proteins contents and minerals. Therefore, effort is needed to improve the nutrient density of *tef* injera by mixing with locally available and protein rich ingredient like lupine which may be one of the ways of combating protein-malnutrition problem of the country. Initiation is taken to investigate the possibilities of improving the nutritional quality of injera by using lupine for the production of injera in complemented with *tef.*

MATERIALS AND METHODS

The experimental materials included *tef* grain and lupine. *Tef* variety DZ-01-196 (magna) was collected from Deber zeit Agricultural Research Centre and two varieties of lupine; debittered lupine seed and Australian sweet lupine were brought from Holetta Agricultural Research centre.

Experimental Design

Mixture design was used in this study to determine the ratio of blends of *tef* and lupine. Maximum and minimum levels of independent variables were first investigated by doing a preliminary analysis in the laboratory (Deber Ziet food science and nutrition) at different proportion of lupines and it was found that a maximum of only 20% lupine will be substituted with tef. The proportion of tef from 80-100% and lupine from 0-20% were used. Each formulation had nine runs and was done in triplicate.

In building the model, a regression equation was established to describe the relationship between the response Y and variable X. A predictive model was generated for the two mixture components as follows:

$$Y = \beta_1X_1 + \beta_2X_2 + \beta_{12}X_1X_2$$

Where: Y is the predicted response, β_1 and β_2 are linear coefficients, β_{12} is the interaction coefficient and X_1 and X_2 are independent variables.

Lupine Flour Preparation

The debittering process for the lupine seeds consisted of cleaning, boiling and debittering. Extraneous material and immature and damaged seeds were removed first. The cleaned seeds were boiled in water (1:3 seeds: water (w/w)) for 50 min to destroy thermolabile anti-nutritional factors and to soften the seeds hull. The boiled lupine seeds were debittered with water at room temperature (~25 ^{0}C). The lupine seeds, during the debittering process, were soaked fully with debittering water and these steps were renewed subsequently in 12 hrs intervals for 144 hrs. Afterwards, the whole seed was de-hulled manually and the kernel was dried at 105 ^{0}C for 3 hrs in oven (Mustafa, 2010). Prior to the chemical analyses, the seeds were dried and milled into a fine powder by using disk attrition mill. Then sieved with sieve size of 750 μm and packed in polyethylene bags and store at 4 ^{0}C until required for analysis (Gitachew *et al.,* 2009).

The Australian sweet lupine flour were prepared by soaking in boiled water for only 5 minutes and dried in oven 105 ^{0}C then the dried sample were undergo dehulling process simply by using local mill and then milled by disk attrition mill.

Preparation of *Tef* Flours

Tef grain were manually cleaned and milled by disk attrition mill to fineness (750 μm) level. The flour was kept in air tight sealed plastic bag at room temperature (AACC, 2000) for the duration of the analysis.

Preparation of composite flour

The flour composite blends contained *tef* and lupine were prepared using a formulation which were generated by mixture design. The dry material individually were blended uniformly to homogenize and then packed in tightly closed clean plastic container that kept at room temperature (25 ± 2°C) until used.

Preparation of fermented dough and baking of *injera*

All ingredients (composite flour + water + *ersho* (starter culture- from previous batch)) were added accurately and the fermentations of the dough were conducted by following the traditional *tef* dough preparation procedure as presented by Bemertu *et al.* (2013). *Injera* of the 23 (three control samples (i.e. 100%) for both varieties) formulations were baked at Debre zeit food science and nutrition laboratory.

Functional Properties

The water absorption capacity of flour sample was measured according to the centrifugation method of Yu *et al.* (2007). The swelling power of flour was determined according to (AACC, 2000) method. The foaming capacity of the samples was determined using the method described by (Yusuf *et al*., 2007). Oil absorption capacity of the flour was determined by the method of Adeleke *et al.* (2010).

Consumer Acceptability of *Tef*-lupine Based *Injera*

A total of 50 members (30 women's and 20 men's) were selected from the staffs, which include laboratory technicians and researchers all aged greater than 30. Injera made from the blend was evaluated for the sensory attributes after 2 hrs of *injera* was baked. The sensory attributes; texture, taste, colour, eye size, eye distribution, rollability, appearance, (i.e. eyes of injera and injera underneath appearance) and over all acceptability, was evaluated using a seven point hedonic scale.

Instrumental Measurements of Number of Eyes and Colours of Blended *Injeras*

Two parallel fluorescent lamps were used to illuminate the sample. The lamps were situated at 10 cm above the sample at the angle of 45^0 of the sample plane to give a uniform light intensity. Finally the images of injera were captured using camera with resolution of 720 x 1280 pixel was located vertically at a distance of 45 cm from the injera sample. Samples were carried out on the basis of CIE L* ab values (Yoseph *et al*., 2019).

Statistical Analysis

The statistical analyses of the data were conducted using SAS statistical software package. Comparisons between the varieties were done using one ways analysis of variance (ANOVA) with a probability P< 0.05. Design-Expert ®, version 7.0, Stat-Ease, (SaMeep104 Inc., Minneapolis, MN USA) was used to generate experimental test trials and to perform regression equations (Okpala and Okoli, 2013).

RESULT AND DISCUSSION

Alkaloid content of lupines

The alkaloid content of two raw lupine varieties was 1.36 mg/100g and 0.75 mg/100g for DLSF (Debittered lupine seed flour) and ASLF (Australian sweet lupine flour), respectively. The alkaloid contents ranged from 6 mg/100g to 7 mg/100g reported by Petterson and Mackintosh (1994), which was higher than this finding. Both lupine varieties had alkaloid content below the maximum level permitted for lupines for human food use of 20 mg/100g as defined by the Australian (FSANZ, 2011) and Great Britain national food standards (MAFF-DOH, 1996).

The effects of lupine varieties and blending ratios on functional properties of tef-lupine composite flour

The sample with 20% DLSF (Debittered lupine seed flour) was had the higher water absorption capacity of 1.39 g/g and followed by 20% ASLF (Australian sweet lupine flour) were 1.31 g/g (Table 1). Whereas 2.5% ASLF blended with *tef* has the lowest water absorption capacity (1.03 g/g). It was revealed from the results that the water absorption capacity increased slightly as the percentage of lupine flour increased. This is maybe due to the hydrophilic nature of lupine proteins (Sathe *et al*., 1982).

The higher foaming capacity (15.77%) was observed in composite flour which has 20% DLSF and followed by 20% of ASL (12.71%). The composite flour with 2.5% blending proportion ASLF had the lowest foaming capacity (2.50%). The ability of the flours to form foam depends on the presence of the flexible protein molecules, which may decrease the surface tension of water (Sathe *et al*., 2009). Protein in the dispersion may cause a lowering of the surface tension at the water air interface, thus always been due to protein, which forms a continuous cohesive film around the air bubbles in the foam (Kaushal *et al.,* 2012).

The swelling power of composite flour was found to be the highest (8.24%) for both lupines at 2.5% blending proportion whereas, the lowest (7.60%) swelling power was observed at 20% of both lupines. Swelling power was high for samples with highest percentage of *tef* flour for both varieties of composite flours. And this is the function of the starch granules, with heat and water starch granules absorbs the water and swells resulting in thicker consistency (Kaushal *et al*., 2012).

The oil absorption capacity is a prominent factor in food formulations as it improves flavour and increases the mouth feel of foods. The oil absorption capacity of composite flour up to 5% of both lupines ranged in between 1.46 g/g and 1.45 g/g without significant difference, while the lowest oil absorption was observed in 20% ASLF with 1.37 g/g. Oil absorption capacity of food component is important for various applications because it relies mainly on this capacity to physically entrap oil by a complex capillary attraction process and this property of flour leads to better flavour retention, a consistency trait and an increase in mouth-feel (Khattab and Arntfield, 2009). Low oil absorption capacity indicates the enhanced hydrophilic character of proteins in the flours. Oil absorption capacity is exhibited by the proteins in the flour, which physically bind to fat by capillary attraction. These proteins expose more non-polar amino acids to the fat and enhance hydrophobicity as a result of which flours absorb oil (Sathe *et al*., 2009).

Table 1. Effect of varieties and blending ratios on functional properties of *tef*-lupine blended flours

***Tef* (%)**	**DLSF (%)**	WAC (g/g)	OAC (g/g)	FC (%)	SP (%)
100	0	1.00±0.01^{i}	1.47±0.01^{a}	1.82±0.00^{n}	8.28±0.01^{a}
100	0	1.01±0.01^{i}	1.47±0.01^{a}	1.89±0.02^{n}	8.28±0.01^{a}
100	0	1.00±0.01^{i}	1.47±0.01^{a}	1.90±0.01^{n}	8.27±0.01^{a}
97.5	2.5	1.08±0.01^{h}	1.46±0.01^{ab}	3.44±0.03^{l}	8.24±0.00^{b}
95	5	1.18±0.01^{g}	1.46±0.01^{ab}	4.98±0.03^{i}	8.21±0.01^{c}
92.5	7.5	1.22±0.01^{f}	1.44±0.02^{cd}	6.35±0.28^{i}	8.01±0.02^{d}
90	10	1.24±0.01^{e}	1.44±0.08^{cd}	8.28±0.06^{g}	7.91±0.01^{g}
90	10	1.23±0.07^{ef}	1.43±0.01^{de}	8.22±0.12^{g}	7.93±0.10^{fg}
85	15	1.33±0.01^{b}	1.42±0.00^{ef}	10.71±0.09^{e}	7.86±0.00^{ij}
82.5	17.5	1.38±0.01^{a}	1.41±0.00^{fg}	12.12±0.27^{c}	7.85±0.01^{jk}
80	20	1.39±0.01^{a}	1.39±0.01^{h}	15.77±0.03^{a}	7.61±0.01^{l}
80	20	1.39±0.01^{a}	1.39±0.01^{h}	15.74±0.06^{a}	7.60±0.01^{l}
80	20	1.38±0.00^{a}	1.39±0.03^{h}	15.74±0.03^{a}	7.61±0.00^{l}
***Tef* (%)**	**ASLF (%)**				
97.5	2.5	1.03±0.01^{j}	1.46±0.00^{ab}	2.50±0.27^{m}	8.24±0.01^{b}
95	5	1.09±0.01^{h}	1.45±0.01^{bc}	4.43±0.28^{k}	8.24±0.01^{b}
92.5	7.5	1.18±0.01^{g}	1.44±0.00^{cd}	5.19±0.27^{j}	8.03±0.01^{d}
90	10	1.22±0.01^{f}	1.42±0.01^{ef}	7.55±0.20^{h}	7.94±0.01^{ef}
90	10	1.22±0.08^{f}	1.42±0.01^{ef}	7.59±0.22^{h}	7.96±0.04^{e}
85	15	1.26±0.01^{d}	1.40±0.01^{h}	10.19±0.27^{f}	7.89±0.01^{h}
82.5	17.5	1.30±0.01^{c}	1.39±0.07^{h}	11.35±0.28^{d}	7.88±0.01^{hi}
80	20	1.31±0.01^{c}	1.37±0.02^{i}	12.71±0.01^{b}	7.62±0.01^{l}
80	20	1.31±0.00^{c}	1.37±0.01^{i}	12.70±0.00^{b}	7.60±0.02^{l}
80	20	1.30±0.01^{c}	1.37±0.01^{i}	12.70±0.01^{b}	7.61±0.01^{l}
CV (%)		3.01	2.51	6.25	3.19
LSD		0.01	0.01	0.16	0.02

Values are in Mean of triplicate data ± SD on dry weight basis. BR = blending ratio, DLSF = debittered lupine seed flour. ASLF= Australian sweet lupine flour, WAC=Water absorption capacities, OAC = Oil absorption capacity, SP = Swelling power, FC = foaming capacity.

Effect of Lupine Variety and Blending Ratio on Sensory Acceptability of *Tef*-lupine Blended *Injera*

The interaction effect of varieties and blending ratios on sensory acceptability was represented by the data shown in Table 2. Colour was not significantly (P>0.05) affected by interaction of lupine varieties and blending ratios. The scores of *injeras* of all combination of the blending ratio and the two lupine varieties varied between 5.36 and 6.18 with no significant difference among them.

The interaction effects of the two factors on sensory acceptability of texture of *injeras* showed that significant differences (P<0.05) existed among the samples. *Injeras* of up to 10% lupine blends did not showed significant difference irrespective of variety, and the majority of the scores were between 5.45 and 6.05 in 7 hedonic scale. Lower scores were recorded for blending ratios of above 10% for both lupine varieties.

The same trend prevailed for sensory acceptability score for sensory attribute taste. *Injeras* of up to 10% lupine blends received scores between 5.59 and 6.14 with no significant difference among them. *Injeras* with more than 10% lupine received lower acceptability scores down to 4.41. As the percentage of lupine increased up to 20% the scores reduced progressively to the indicated level for both lupine varieties.

The interaction effect of blending ratio and lupine varieties on the rollability of *injeras* showed that significant difference (P<0.05) exists among the samples. The rollability sores of *injeras* blended up to 10% lupine score between 6.09 up to 5.64 with no significant difference among them for both varieties but DLSF variety blend extends its acceptability score up to 17.5% with no significant difference with 10% of ASLF. So DLSF was a good rollability with greater blending ratio than ASLF.

The interaction effect of the two factors (lupine varieties and blending ratios) on eye size of *injera* showed that significant differences (P<0.05) existed among the samples. The sensory acceptability for the attribute eye size of *injera* of up to 10% lupine blends received scores between 5.77 and 6.08 with no significant statistical difference among them. *Injera* with more than 10% lupine blend received lower acceptability scores decreased up to 3.23. As the percentage of lupine increasing, the scores for eye size of *injera* decreased in each lupine variety.

The interaction effect of the two factors (varieties and blending proportions) on eye distribution of *injeras* showed that significant differences (P<0.05) existed among the samples. The sensory acceptability score for the eye distribution *injera* with up to 10% of DLSF between 5.59 and 6.14 with no significant difference, whereas for ASLF variety blends with up to 10% was ranged between 5.68 and 6.05 without statistical difference among them.

Table 2. Interaction effects of lupine varieties and blending ratio on sensory acceptability of *tef*-lupine blended *injera*

***Tef* %**	**DLSF %**	Colour	Texture	Taste	Rollability	No eye	Eye size	Eye distrib.	T and B	Aroma	OAA
100	0	6.05 ± 0.65^{ab}	5.82 ± 0.96^{abc}	6.09 ± 0.68^{a}	5.98 ± 0.76^{abcd}	5.95 ± 0.75^{ab}	6.09 ± 0.89^{ab}	5.89 ± 1.10^{abcde}	5.93 ± 0.94^{abc}	6.18 ± 0.75^{a}	5.91 ± 0.68^{abc}
100	0	5.82 ± 0.80^{ab}	6.23 ± 0.48^{a}	5.59 ± 1.09^{c}	5.77 ± 1.07^{bcd}	6.02 ± 0.71^{ab}	6.32 ± 0.65^{a}	6.11 ± 0.72^{ab}	6.09 ± 0.71^{ab}	6.02 ± 0.58^{ab}	6.14 ± 0.46^{a}
100	0	6.09 ± 0.97^{ab}	6.18 ± 0.47^{a}	5.95 ± 1.01^{abc}	5.73 ± 1.03^{bcd}	6.19 ± 0.87^{a}	6.00 ± 0.68^{ab}	6.02 ± 0.92^{abc}	5.94 ± 0.97^{abc}	5.95 ± 0.80^{abcd}	5.89 ± 0.77^{abc}
97.5	2.5	5.91 ± 0.87^{ab}	5.59 ± 1.01^{bcd}	5.91 ± 1.02^{abc}	6.00 ± 0.69^{abc}	6.23 ± 0.69^{a}	6.00 ± 0.76^{ab}	5.59 ± 1.03^{def}	5.95 ± 0.65^{abc}	5.91 ± 0.68^{abcd}	5.91 ± 0.68^{abc}
95	5	5.91 ± 0.68^{ab}	6.05 ± 0.72^{ab}	5.32 ± 1.04^{c}	5.64 ± 0.49^{cd}	6.19 ± 0.72^{a}	5.95 ± 0.79^{ab}	6.14 ± 0.77^{ab}	5.82 ± 0.91^{abc}	5.86 ± 0.77^{abcd}	5.95 ± 0.72^{abc}
92.5	7.5	6.14 ± 0.71^{a}	5.82 ± 1.09^{abc}	6.14 ± 0.71^{a}	6.05 ± 0.84^{ab}	6.14 ± 0.71^{a}	5.86 ± 1.04^{bcd}	5.95 ± 0.79^{abcd}	5.91 ± 0.87^{abc}	6.00 ± 0.76^{abc}	6.05 ± 0.74^{ab}
90	10	5.86 ± 0.94^{ab}	6.00 ± 0.69^{abc}	5.59 ± 0.96^{c}	6.09 ± 0.53^{a}	6.20 ± 0.67^{a}	6.08 ± 0.68^{ab}	6.23 ± 0.94^{a}	5.59 ± 0.96^{c}	5.82 ± 0.73^{bcd}	6.06 ± 0.56^{ab}
90	10	6.18 ± 0.59^{a}	5.73 ± 0.99^{cde}	6.00 ± 0.76^{ab}	5.78 ± 1.02^{abcd}	5.73 ± 0.62^{bc}	5.82 ± 0.85^{bcd}	5.96 ± 0.94^{abcd}	6.00 ± 0.62^{ab}	6.22 ± 0.69^{a}	6.18 ± 0.58^{a}
85	15	6.05 ± 0.72^{ab}	4.86 ± 0.71^{gh}	5.64 ± 0.49^{bc}	6.00 ± 0.54^{abc}	5.45 ± 0.81^{cd}	5.55 ± 0.60^{cd}	5.77 ± 0.53^{bcde}	5.45 ± 1.01^{cd}	5.27 ± 0.83^{e}	5.68 ± 0.48^{cd}
82.5	17.5	5.82 ± 0.85^{ab}	4.91 ± 0.81^{gh}	4.91 ± 0.61^{d}	5.75 ± 0.70^{bcd}	5.09 ± 0.58^{de}	4.95 ± 0.79^{e}	5.50 ± 0.60^{ef}	5.59 ± 0.86^{c}	5.00 ± 0.82^{f}	4.73 ± 0.55^{ef}
80	20	5.86 ± 0.89^{ab}	4.45 ± 0.60^{hi}	5.41 ± 0.80^{c}	4.55 ± 0.51^{g}	4.68 ± 0.65^{ef}	4.00 ± 0.69^{f}	4.68 ± 0.65^{g}	5.00 ± 0.65^{de}	5.27 ± 0.63^{ef}	4.61 ± 0.69^{f}
80	20	5.68 ± 0.84^{abc}	3.50 ± 1.08^{j}	3.82 ± 0.80^{l}	5.14 ± 0.77^{f}	3.27 ± 0.77^{h}	3.55 ± 0.60^{g}	4.27 ± 0.77^{h}	4.86 ± 0.66^{e}	5.09 ± 0.65^{d}	4.20 ± 0.69^{g}
80	20	5.73 ± 1.08^{ab}	4.55 ± 0.91^{hi}	5.00 ± 0.76^{d}	3.82 ± 0.66^{h}	4.82 ± 0.78^{ef}	3.45 ± 0.60^{g}	4.82 ± 0.80^{g}	4.01 ± 0.72^{fg}	5.41 ± 0.61^{ef}	4.59 ± 0.56^{f}
***Tef* %**	**ASLF %**										
97.5	2.5	6.00 ± 0.62^{ab}	5.95 ± 0.58^{abc}	6.09 ± 0.75^{a}	5.77 ± 0.87^{abcd}	6.18 ± 0.73^{a}	5.77 ± 0.52^{bcd}	6.00 ± 0.61^{abc}	5.86 ± 0.41^{abc}	6.00 ± 0.61^{abc}	5.91 ± 0.46^{abc}
95	5	5.95 ± 0.65^{ab}	5.45 ± 1.10^{ef}	5.77 ± 0.81^{abc}	5.68 ± 0.41^{cde}	6.14 ± 0.49^{a}	5.95 ± 0.45^{ab}	5.68 ± 0.48^{cde}	6.05 ± 0.35^{ab}	5.82 ± 0.54^{bcd}	5.81 ± 0.55^{bc}
92.5	7.5	5.64 ± 1.05^{abc}	6.00 ± 0.25^{abc}	6.11 ± 0.71^{a}	6.00 ± 0.61^{abc}	6.05 ± 0.65^{ab}	6.00 ± 0.37^{ab}	5.86 ± 0.17^{abcde}	6.17 ± 0.46^{a}	5.95 ± 0.34^{abcd}	5.82 ± 0.47^{bc}
90	10	6.00 ± 0.69^{ab}	5.64 ± 0.95^{bcd}	6.00 ± 0.62^{ab}	6.07 ± 0.57^{ab}	6.25 ± 0.77^{a}	5.82 ± 0.46^{bcd}	6.05 ± 0.55^{abc}	5.73 ± 0.32^{bc}	6.14 ± 0.43^{ab}	6.00 ± 0.28^{abc}
90	10	5.82 ± 0.91^{ab}	6.00 ± 0.69^{abc}	5.59 ± 0.96^{c}	5.64 ± 0.27^{cde}	6.03 ± 0.42^{ab}	6.05 ± 0.55^{ab}	5.68 ± 0.24^{cde}	6.05 ± 0.35^{ab}	5.64 ± 0.28^{cd}	5.97 ± 0.53^{abc}
85	15	5.77 ± 0.87^{ab}	5.27 ± 0.88^{fg}	5.41 ± 0.91^{c}	5.32 ± 0.49^{ef}	5.59 ± 0.55^{c}	5.55 ± 0.51^{cd}	5.27 ± 0.67^{fg}	5.95 ± 0.22^{abc}	5.59 ± 0.34^{cde}	5.36 ± 0.56^{d}
82.5	17.5	5.68 ± 1.01^{abc}	4.86 ± 0.56^{gh}	4.68 ± 0.95^{de}	4.68 ± 0.54^{g}	5.50 ± 0.43^{cd}	5.68 ± 0.46^{cd}	5.00 ± 0.56^{g}	4.81 ± 0.17^{e}	5.18 ± 0.58^{f}	4.98 ± 0.40^{e}
80	20	5.59 ± 0.85^{abc}	4.50 ± 0.51^{hi}	4.41 ± 0.91^{e}	5.00 ± 0.18^{fg}	4.55 ± 0.44^{f}	4.23 ± 0.56^{f}	3.23 ± 0.26^{j}	4.94 ± 0.42^{e}	5.50 ± 0.51^{ef}	4.52 ± 0.16^{fg}
80	20	5.66 ± 0.58^{abc}	4.36 ± 0.73^{i}	4.86 ± 0.71^{d}	4.59 ± 0.62^{g}	3.72 ± 38^{g}	4.77 ± 0.48^{e}	3.95 ± 0.36^{hi}	4.05 ± 0.50^{fg}	5.35 ± 0.22^{ef}	4.70 ± 0.25^{ef}
80	20	5.84 ± 0.90^{ab}	4.23 ± 1.07^{i}	4.91 ± 0.87^{d}	5.28 ± 0.64^{ef}	3.86 ± 0.50^{g}	3.23 ± 0.25^{g}	4.14 ± 0.47^{h}	4.27 ± 0.31^{f}	5.14 ± 0.17^{f}	4.45 ± 0.51^{fg}
CV (%)		13.94	21.28	18.16	19.54	21.44	21.32	23.66	20.81	19.62	19.80
LSD		0.51	0.42	0.40	0.41	0.41	0.37	0.40	0.39	0.36	0.32

The interaction of the two factors on the number of *injera* eyes of *injeras* showed that significant differences (P<0.05) existed among the samples. *Injera* of up to 10% lupine blends did not show significant difference irrespective variety, and the majority of the scores were between 6.03 and 6.25 in 7 hedonic scales. *Injeras* of up to 17.5% of both lupines varieties had sensory acceptability of numbers of eyes with scores above 5 in 7 hedonic scales even if they were statically different.

Regarding the acceptability of the top and bottom surface of *injera* scores were significantly (P<0.05) affected by both lupine varieties and blending ratios. *Injeras* of up to 10% lupine blends did not show significant difference irrespective variety, and the majority of the scores were between 5.59 and 6.17 in 7 hedonic scale.

Finally, the overall acceptability of blended *injeras* were significantly (P<0.05) affected by varieties and blending ratio interactions. The scores given to overall acceptability showed that *injeras* with up to 10% lupine received the scores of 5.81 and 6.17 for varieties of DLSF and ASLF, respectively. The lowest scores were 4.20 and 4.45 for 20% lupine mix with DLSF and ASLF variety, respectively. The result showed that increasing lupine proportion lowered the overall acceptability of the *injeras.* All the scores indicated that all *tef injeras* mixed with lupine up to 15% received above 5 (like slightly) scores level of acceptability in 7 hedonic scale.

4.3.3. Predictive Models for Sensory Acceptability of *Tef*- lupine *Injera*

The models, which are listed in Table 3 were used to predict the sensory acceptability of different sensory attribute parameters of blended *injera*. Almost in all sensory attributes of acceptability's *tef* has scored the highest coefficient of values.

Table 3. Regressions models for sensory acceptability of *tef*-lupine *injera*

***Tef* : DLSF**	Predictive model $Y = \beta_1X_1 + \beta_2X_2 + \beta_{12}X_1X_2$	Model (Prob>F)	Adj R^2	R^2	Lack of fit
Colour	Y=6.0456T+4.95369L	0.0438*	0.8585	0.8594	0.4744(ns)
Texture	Y=5.9356T-45.63178L+54.84065T*L	0.0001*	0.7984	0.8320	0.8682(ns)
Taste	Y=5.92417T-55.3443L+65.75844T*L	0.0213*	0.8904	0.8953	0.7207(ns)
Rollability	Y=5.74571T-64.0816L+80.74071T*L	0.0041*	0.8001	0.8668	0.5466(ns)
Number of eyes	Y=6.07035T-68.0292L+81.6342T*L	0.0002*	0.7858	0.8215	0.9985(ns)
Eye size	Y=5.92844T-89.4311L+106.0471T*L	0.0001*	0.9112	0.9260	0.2855(ns)
Eye distribution	Y=5.76999T-65.5811L+82.48038T*L	0.0001*	0.8124	0.8437	0.3850(ns)
Top and bottom	Y=5.88136T-41.4934L+52.08124T*L	0.0009*	0.7046	0.7538	0.8202(ns)
Aroma	Y=5.87866T-23.9048L+32.60378T*L	0.0018*	0.6609	0.7174	0.1999(ns)
OAA	Y=5.90447T-66.9367L+81.98915T*L	0.0001*	0.9182	0.9319	0.3184(ns)
***Tef* : ASLF**					
Colour	Y=6.02274T+3.9958lL	0.0023*	0.6068	0.6192	0.8386(ns)
Texture	Y=5.9356T-45.63178L+54.84065T*L	0.0001*	0.8516	0.8763	0.6131(ns)
Taste	Y=5.79027T-42.65319L+53.87613T*L	0.0002*	0.7919	0.8266	0.4705(ns)
Rollability	Y=5.9817T+1.25254L-1.09608T*L	0.0012*	0.5958	0.6295	0.3223(ns)
Number of eyes	Y=6.01029T-84.84753L+102.33463T*L	0.0001*	0.8747	0.8956	0.3616(ns)
Eye size	Y=5.89723T-72.57146L+88.07295T*L	0.0012*	0.6882	0.7401	0.6236(ns)
Eye distribution	Y=5.81144T-80.42703L+95.89247T*L	0.0001*	0.8745	0.8954	0.6500(ns)
Top and bottom	Y=5.85849T-68.28695L+83.88113T*L	0.0001*	0.8259	0.8549	0.6555(ns)
Aroma	Y=5.99082T+2.087027L-2.219016T*L	0.0001*	0.5717	0.6074	0.5119(ns)
OAA	Y=5.90297T-46.70368L+57.44818T*L	0.0001*	0.9312	0.9427	0.2688(ns)

βi = L-pseudo-component value, (T) = *Tef,* (L) = Lupine, Y= response for each parameters * = Significant at P < 0.05, (ns) = not significant, OAA = overall acceptability, ASLF = Australian sweet lupine flour and DLSF = debittered lupine seed flour

Effect of Varieties and Blending Ratio on Number of Eyes and Colour of *Tef*-lupine *Injera*

The interaction effect of the varieties and blending proportions on the number of eyes of *injeras* is represented by the data shown in Table 4. The numbers of holes of *injera* was significantly (P<0.05) affected by interaction effect. From the interactions of lupine varieties and blending ratio, the number of eyes of the blended *injera* up 10% of both lupines ranges from 18805.33 to 18961.21 with no significance difference among them. While, the minimum number of eyes of *injeras* were obtained from 20% (14220.33) ASLF variety followed by 20% (14222.67) DLSF variety with no statistical differences between them. This is due to the protein content difference between the raw materials (Hall *et al*., 2004).

The colour of blended *injera* were significantly (P < 0.05) affected by interactions of lupine varieties and blending proportions Table 4. From the interactions of the two varieties of lupine with blending ratio, the L* values of *injera* show increasing trends with increasing the blending ratio of lupine for both varieties. From the blending ratio interactions effect a higher L*value was obtained between 79.84 and 76.69 from 20 and 17.5% of both lupines varieties were blended with *tef* without statically difference. As the proportion of lupine increased there was also an increasing of yellowness (b) colour of the product. This effect was expected because of the more intense yellow colour of lupine flour. These results agree with those obtained by Dodok *et al*. (1993), who observed that Lupine seeds contain high levels of carotenoids and zeaxanthin which give the cotyledon (kernel) bright yellow colour and triggered the change in the yellowish colour of bread produced from a composite flour of wheat and lupine.

Table 4. Effect of variety and blending ratio on number of eyes and colour of *tef*-lupine *injera*

***Tef* %**	**DLSF %**	Number of eyes	L*	a	b
100	0	18953.12±64.12[ab]	71.66±0.05[fgh]	0.45±0.21[b]	5.13±0.07[b]
100	0	19017.67±51.51[a]	71.45±0.39[fgh]	0.80±0.10[a]	5.10±0.37[b]
100	0	18956.67±58.96[ab]	71.79±1.17[fgh]	0.28±0.63[c]	5.16±2.82[b]
97.5	2.5	18929.33±63.89[ab]	72.77±1.44[efgh]	0.18±0.20[c]	7.12±0.07[b]
95	5	18832.01±41.35[ab]	74.79±0.36[cdef]	0.21±0.09[c]	7.52±1.60[ab]
92.5	7.5	18796.67±12.04[ab]	75.42±1.01[bcdef]	0.33±0.20[c]	7.70±0.62[ab]
90	10	18791.33±40.93[ab]	75.20±1.12[bcdef]	0.13±0.26[def]	8.80±0.93[ab]
90	10	18828.08±41.05[ab]	75.29±1.07[bcdef]	0.12±0.59[def]	7.78±2.23[ab]
85	85.15	16496.33±52.53[c]	76.55±0.05[bcde]	0.10±0.76[def]	9.09±0.38[ab]
82.5	17.5	15449.67±30.55[d]	76.96±0.21[bcd]	0.06±0.47[ef]	9.38±1.42[a]
80	20	14225.67±39.84[e]	77.55±0.70[abc]	0.08±0.11[def]	9.42±1.88[a]
80	20	14233.07±21.15[e]	77.69±1.58[abc]	0.09±0.68[def]	9.42±1.20[a]
80	20	14222.33±13.65[e]	77.67±2.47[abc]	0.07±0.11[def]	9.45±1.14[a]
***Tef* %**	**ASLF%**				
97.5	2.5	18961.21±21.26[ab]	72.87±0.36[efgh]	0.21±0.14[c]	3.25±0.28[c]
95	5	18834.33±19.29[ab]	73.94±0.02[defg]	0.17±0.20[d]	4.17±0.08[c]
92.5	7.5	18821.05±18.88[ab]	75.88±2.18[bcdef]	0.16±0.29[de]	5.10±0.46[b]
90	10	18805.33±15.86[ab]	75.93±3.63[bcdef]	0.13±0.30[def]	6.13±0.24[bc]
90	10	18839.52±17.55[ab]	76.21±1.89[bcdef]	0.14±0.22[def]	6.15±0.08[bc]
85	15	16500.33±21.39[c]	77.11±0.24[abc]	0.10±0.09[def]	8.82±0.29[ab]
82.5	17.5	15458.33±11.63[d]	77.93±11.02[abc]	0.07±0.07[def]	8.94±1.65[ab]
80	20	14232.33±13.05[e]	79.84±0.16[a]	0.07±0.15[def]	9.44±1.15[a]
80	20	14244.13±11.79[e]	79.81±5.77[a]	0.05±0.28[f]	9.45±0.47[a]
80	20	14220.43±12.52[e]	79.80±4.57[a]	0.05±0.25[f]	9.47±0.25[a]
CV (%)		7.91	2.94	2.75	2.89
LSD		247.47	4.71	0.10	2.25

Values are Mean ± SD in a column with the same letter are not significantly different (p>0.05). DLSF = debittered lupine seed flour and ASLF= Australian sweet lupine flour.

Predictive Models for Number of Eyes and Colour Values of *Injera*

The predictive model of numbers of *injeras* eyes and colour especially lightness which is the more dominant are shown below in Table 5. *Tef* shows the greater coefficient value for number of *injeras* eyes in both lupine varieties. The higher the coefficient value indicates that the higher effect on the response on the produced *injeras*. The colour (lightness) of produced *injera* was scored higher coefficient values by lupine varieties rather than *tef* and the blended *injera* colour determined by the software results indicate there was not agreed with the sensory acceptability test scores these was due to the subjective character of sensory tests panellists but not instruments Dodok *et al*., 1993).

Table 5. Regressions models for eyes and colour of *tef*-lupine *injera* by software

***Tef*: DLSF**	Predictive model $Y = \beta_1X_1 + \beta_2X_2 + \beta_{12}X_1X_2$	Model Prob>F	Adj R^2	R^2	Lack of fit
Number of eyes	Y= 18974.19101T- 0.000012L+0.000015T*L	0.0001*	0.9898	0.9998	0.5578(ns)
Lightness	Y=71.40104T+80.5358L+34.03937T*L	0.0058*	0.9691	0.9743	0.5734(ns)
***Tef*: ASLF**					
No of Eyes	Y= 18954.48895T-0.000014L+0.000017T*L	0.0001*	0.9899	0.9999	0.0881(ns)
Lightness	Y=71.70969T+81.48756L+37.08492T*L	0.0001*	0.98	0.9833	0.1505(ns)

βi = coefficients, (T) = *Tef*, (L) = Lupine, Y = response for each parameters, * = Significant at $P < 0.05$, (ns) = not significant, ASLF = Australian sweet lupine flour and DLSF = debittered lupine seed flour

CONCLUSION

Adding lupine proportion had significantly increases water absorption capacity and foaming capacity, and decreases the oil absorption capacity and swelling power of composite flour. The acceptability of colour, texture, eye size, number of eyes, eye distribution, aroma, taste, rollability, eyes and top and bottom surface and overall acceptability of *tef*-lupine *injera* reduced when lupine blending ratio exceeded 10%. Overall acceptability and some sensory attributes scores were higher for *injeras* with 10% DLSF blend with *tef* as compared to all the rest of the *injera* products. *Tef injeras* produced by mixing with up to 15% lupine were found acceptable by consumers having scores of greater than 5 in in a scale of 7 points. Generally as the proportion of lupine ratio increased the overall acceptability of *injera* decreased. Instrumental measurements of colour values of composite *injera* shows that number of eyes decreased as lupine proportion increased which is in agreement with sensory evaluation and colours (lightness) were increased for both lupine varieties, disagreed with the sensory evaluation.

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Conflict of interest
The authors declare no competing interest.

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