CHAPTER-IX
CHARACTERIZATION OF DEVELOPED BAKERY PRODUCTS
9.1. INTRODUCTION

Flour is the main element of the bakery products. Wheat is ideal flour or raw material for baking purpose (Diana et al., 2007). Flour characteristic and requirements are quite different for different bakery products and are almost opposite properties are required for cookies and bread. To prepare sweet biscuit low protein soft wheat is required. The preference of damage starch and low protein content could be attributed to their role in water binding activity (Edwards, 2007).

To prepare highly nutritious cookies, other cereal and legume could be blended to the wheat flour. Milligan et al. (1981), explained the concept of composite flour and stated it as a mixture of two or more type of ingredients to replace wheat flour partially. Noorfarahzilah et al. (2014) reviewed the utilization of composite flour in development of different food products.

Legumes contain higher quantity of protein content and are hard whereas certain cereal do not have gluten like proteins, therefore cannot be directly employed to cookies preparation using regular process. Elin et al. (2003) observed the trend of using composite flours with high lysine content for baked products to enhance its nutritional index. Partial replacement of wheat flour with cowpea flour, fermented and germinated flour gave appropriate results for rheology of baked products. A correlation was found between flour water absorption with the increase in the proportion of cowpea flour due to high protein content and damaged starch.

Other than flour, some components which could affect the rheology of cookies dough are sugar, fat and water. Maache-Rezzoug et al. (1988) observed the effect of these
components on the rheology of biscuit dough and quality of product. High sugar biscuit were observed with cohesive structure and crispy texture. Increment of fat leads to friable structure and soft texture, accompanied by less weight and thickness of biscuit. Increasing protein content in biscuit leads to major changes in dough rheology and dimensions of cookies.

Effect of increase in the protein content was also studied by De La Roche and Fowler (1975). Increase in protein content affects dough rheology and length of biscuit after baking. The qualitative and quantitative relation of gluten in biscuit making is not very much clear. However the source of gluten tends to have significant effect on dough rheology. Protein affects the dough rheology by modifying elasticity and loss modulus. Both elasticity and loss modulus increased by adding protein to base formulation.

Canalis et al. (2017) observed dough properties as affected by fibers. Utilization of corn starch and modified starch affects the quality of biscuit whereas usage of inulin improved biscuit quality by enhancing the capacity of dough to spread. Also the inulin fortified biscuit were observed with high sensory attributes. Therefore the effect of fortification of fiber depends on the type of fiber used and extent of fortification.

Viscoelastic properties associated with dough rheology and mechanical properties depend on the water molecule distribution in dough. Chatakanonda et al. (2003) observed the influence of water on relaxation behavior in flour. Two distinct regions of relaxation time were observed by many researchers in starch-water mixtures (Tananuwong et al., 2004; Choi and Kerr, 2003).

Increased water absorption, oil absorption and protein content not only affect the rheology of dough but also affect the final product texture and shelf life. Studies revealed the effect of sorption behavior and water activity of food as key factor to determine the shelf life
of food. The extent of moisture contained by food facilitates the degradation of food by chemical or microbiological means (Tung et al., 2004).

In the present chapter, characterization of optimized bakery products (Cookies) (refer to section 8.3.), prepared from different formulations has been covered. The flour blends of cookies were analyzed for functional and pasting properties, whereas final formulated cookies were characterized for nutritional compositional analysis, texture profile and color characteristic along with sensory characteristics.

9.2. MATERIALS AND METHODS

9.2.1. MATERIALS

9.2.1.1. Preparation of raw materials

Raw material was prepared in the form of blended flours as per the optimized flour proportions (refer to Chapter-VIII, Section 8.3). 4 different type of cookies sample were prepared (refer to section 8.2.2.1) from the optimized blends of these flours which includes:

- Formulation-I (wheat based cereal fortified),
- Formulation-II (wheat based legume fortified cookies),
- Formulation-III (triticale based cereal fortified cookies)
- Formulation-IV (triticale based legume fortified cookies)

9.2.2. METHODS

9.2.2.1. Functional and pasting properties of formulated composite flours

9.2.2.1.1. Water absorption capacity

Procedure refer to section 5.2.2.1

9.2.2.1.2 Oil absorption capacity

Procedure refer to section 5.2.2.2.
9.2.2.1.3. Sedimentation value

Procedure refer to section 5.2.2.5

9.2.2.1.4. Foaming capacity

Procedure refer to section 5.2.2.4

9.2.2.1.5. Emulsification capacity

Procedure refer to section 5.2.2.6.1.

9.2.2.1.6. Pasting properties

Pasting properties of composite flour of different formulations were estimated using RVA (Rapid Visco Analyzer-RVA Tecmaster, Perten, Australia) using standard testing profile-1. Appropriate sample around 3-5g as described in manual was taken and mixed with 25 ml water. The mixture was stirred for 10 sec at 960 rpm and then 160 rpm. Initially temp-time combination of 50°C for 1 min was employed and then after equilibrium temperature raised to 95°C for 5 min. After the procedure cooling cycle was carried and temperature decreased to 50°C in 3 min. Results were recorded from graph as Peak viscosity (PV), trough viscosity (TV), Breakdown value, final viscosity (FV), Setback, pasting temperature (PT).

![Figure 9.1 Typical RVA pasting curve explaining different pasting parameters](image-url)
9.2.2.2. Characterization of prepared cookies from optimized formulations

9.2.2.2.1. Compositional analysis

9.2.2.2.1.1. Moisture content

Moisture content was determined using oven drying method (AOAC, 1995). 5g of sample was taken in dried and pre-weighted moisture dish. The moisture dish containing sample was placed in oven for 3-4h which was operated at 105±1°C. After 2 hours repeated weighing was done at 15 min intervals until the constant readings were obtained. Moisture content was calculated in terms of percentage as follows:

\[
\text{Moisture content (\%)} = \frac{(W_2-W)}{(W_1-W)} \times 100
\]

\text{(Equation 9.1)}

Where

\[W= \text{Weight of empty moisture dish}\]
\[W_1= \text{Weight of moisture dish with sample before drying}\]
\[W_2= \text{Weight of moisture dish with sample after drying}\]

9.2.2.2.1.2. Protein content

Cookies blend contains different amount of cereal and legumes, therefore it was not appropriate to estimate protein content by Kjeldahl method, due to mixed nitrogen factors. To avoid confusion Lowry’s method was used to estimate protein content of cookies prepared from blend of different flours.

Reagents used were 1% sodium-potassium tartrate, 2% NaHCO₃ (in 0.1N NaOH), 0.5% CuSO₄. Working reagents 48ml of 2% NaHCO₃ + 1 ml of 1% sodium-potassium tartrate + 1ml of 0.5% CuSO₄, Folin-phenol (2N). 1 ml of working standard was prepared in 5 test tubes and taking distilled water as blank. 4.5 ml of working reagent was added to each test tube and incubated in boiling water bath for 10 min. After incubation 0.5 ml of folin-phenol
reagent was added and further incubated in boiling water bath for 30 min. Sample were extracted in test tubes and centrifuged. Similar treatment to samples were given with above mentioned reagents. Absorbance was measured at 660nm to plot standard graph. Protein was estimated from standard curve.

9.2.2.2.1.3. Total carbohydrate content

Procedure refer to section 4.2.2.1.3

9.2.2.2.1.4. Crude fat content

Procedure refer to section 4.2.2.1.8

9.2.2.2.1.5. Crude fiber

Procedure refer to section 4.2.2.1.9.

9.2.2.2.1.6. Ash content

Procedure refer to section 4.2.2.1.2.

9.2.2.2.2 Texture profile analysis

Three point bend test was performed to estimate the texture parameters (hardness, fracturability and cohesiveness) of optimized cookies. Parameters like hardness, cohesiveness can be estimated from force to deformation curve of compression test (Meullent and Gross, 1999). Texture profile was analyzed according to the procedure followed in section 8.2.2.4.2.

9.2.2.2.3. Colour Characteristics

Colour value of different flours was estimated by using Hunter lab (Hunter lab digital colorimeter, D25M, Reston, Virginia) equipped with I-type optical sensor (D-25) and DP-9000 processor. $L^*$ depicts lightness, "a" indicates redness (+)/greenness (-) and "b" indicates yellowish (+)/blueness (-) of the sample. Values of sample were compared with the
standard colored reference tile \((L_0=25.54, a_0=28.89 \text{ and } b_0=12.03)\). Cookies sample were placed on specimen port and values of \(L^*, a^*, b^*\) were recorded.

9.2.3. Statistical analysis

Refer to section 3.2.3.

9.3. RESULTS AND DISCUSSION

9.3.1. Functional properties of optimized blended flours

Due to blending of different flours having different functional properties the resultant properties of composite flours were changed. Functional properties like water absorption capacity, oil absorption capacity, sedimentation value, foaming capacity and emulsification capacity were observed as reported in Table 9.1. Raw wheat flour was treated as control. These properties are type of biophysical properties which revealed the interaction of molecules with the ingredients and thus provide the formal idea of flour behavior for product formulation.

Water absorption capacity of control sample was lower among all other analyzed flours. Legume blended combinations of both triticale and wheat exhibited higher value of water absorption capacity, followed by cereal blends. There was no significant difference between the water absorption capacities of legume blend of wheat and triticale, and values observed were 1.46±0.04 (g/g) and 1.45±0.02 (g/g) respectively. Cereal blend of wheat and triticale closely followed the latter and exhibited the values 1.39±0.02 (g/g) and 1.41±0.03 (g/g) respectively. Water absorption capacity of control sample was 1.33±0.02 (g/g). Difference in the water absorption capacities of different flour could be attributed to the composition of flours blends. Although germination enhanced the disruption of polysaccharides which led to more damaged starch and thus increased water absorption
capacity. Also due to the protein content which tended to absorb more water, caused the variation in water absorption capacity (Chauhan et al., 2015).

Like water absorption capacity, oil absorption capacity followed the similar pattern of absorption with slight variation. Oil absorption capacity was higher in wheat based legume fortified blend (1.38±0.03 g/g) followed by triticale based cereal fortified blend (1.22±0.04 g/g). Wheat based cereal fortified and triticale based legume fortified blend were observed with similar oil absorption capacities. Oil absorption capacity of control was lower and reported as 1.16±0.02 g/g oil absorbed. Increase in the protein content and hydrophobic interaction of resultant protein of blended flours could attributed to the variation in oil absorption capacities (Chiemela et al., 2009).

Sedimentation value of raw wheat flour was higher due to higher gluten fraction of protein. With blending of different flours and germination, there was reduction in the total gluten fraction whereas gluten was replaced with some other protein fractions which led to lowered value of sedimentation. Sedimentation value of raw wheat flour was 60.01±0.01 ml. Legumes blended in wheat and triticale exhibited the sedimentation value of 28.04±0.02 ml and 24.16±0.02 ml. Cereal fortified blends has shown lower most values of sedimentation which were reported as 22.10±0.04 ml in wheat based combination and 19.11±0.02 ml in triticale based composite flour.

Blending of flour affected the foaming capacity of flours. Foaming capacity is a function of surface properties of some proteins (Sibian et al., 2017). With the distribution of different kind of proteins and their interactions in composite flours surface properties of resultant protein proportion altered. Control raw wheat flour has shown slightly lower value of foaming capacity (12.76±0.01%), which was closely followed by wheat based cereal fortified flour (12.95±0.02%). Triticale based cereal fortified flour was reported with
foaming capacity of 13.41±0.03%, whereas legume based blends exhibited higher foaming capacity and were reported as 15.17±0.04% for triticale based legume fortified flour and 21.43±0.03% for wheat based legume fortified flour blend.

Emulsification capacity of different flour combination were also affected by the blending of different proportions of flour. Triticale based legume fortified blend exhibited lower value of emulsification capacity which was reported as 17.82±0.03 ml, whereas triticale based cereal fortified flour was reported with highest emulsification capacity. Wheat flour blend of cereal was lower in emulsion formation capacity as compared to legume blend and exhibited the values of 19.32±0.02 and 24.45±0.04 respectively. The variation in the emulsification capacities could be attributed to the protein lipid interactions (Millward and Rivers, 1988; Sibian et al., 2017), with the novel blends different kind of proteins and lipids interacted and thus exhibited different emulsification capacities.

9.3.2. Rheological properties of optimized composite flours

Rheology of blended doughs were compared by using Rapid Visco-Analyser (RVA), which has been used to observe the pasting properties related to flours and starches. RVA gave multi-parameter values like peak viscosity, trough viscosity, breakdown, final viscosity, setback viscosity and pasting temperature to observe behavior of viscosity related molecules like amylose-amylopectin at different range of temperature.

Peak viscosity is a measure of ability of swelling of starch before physical breakdown of starch molecules occurs and also corresponds to water binding capacity of starch. With the debranching and disruption of starch molecule due to germination, peak viscosity started declining. Peak viscosity of control sample was quite high as compared to blended flours. Peak viscosity (cP) of control flour sample was observed as 928.00±0.34 cP. Legume based cookies flour were ranked lower in their peak viscosities after control flour sample which in
turn were followed by cereal blends. Higher peak values corresponded to higher gel strength due to more intact starch molecules. Higher degradation of starch molecules led to lower peak viscosity values in cereal blends. Peak viscosities of wheat and triticale based cereal blends were observed as 329.00±0.54 cP and 373.00±0.42 cP respectively. Lower degradation in wheat and triticale based legume blended flours were observed with the peak viscosities of 519.00±0.47 cP and 581.00±0.44 cP respectively.

Table 9.1. Functional properties of control and optimized flour blends

<table>
<thead>
<tr>
<th>Functional properties</th>
<th>Control</th>
<th>Triticale based cereal fortified</th>
<th>Wheat based cereal fortified</th>
<th>Triticale based legume fortified</th>
<th>Wheat based legume fortified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water absorption capacity (g/g water absorbed)</td>
<td>1.33±0.02&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.41±0.03&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.39±0.02&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>1.45±0.02&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>1.46±0.04&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Oil absorption capacity (g/g oil absorbed)</td>
<td>1.16±0.02&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.22±0.04&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>1.21±0.02&lt;sup&gt;cb&lt;/sup&gt;</td>
<td>1.21±0.03&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>1.38±0.03&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Sedimentation value (ml)</td>
<td>60.01±0.01&lt;sup&gt;a&lt;/sup&gt;</td>
<td>19.11±0.02&lt;sup&gt;e&lt;/sup&gt;</td>
<td>22.10±0.04&lt;sup&gt;d&lt;/sup&gt;</td>
<td>24.16±0.02&lt;sup&gt;c&lt;/sup&gt;</td>
<td>28.04±0.02&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Foaming capacity (%)</td>
<td>12.76±0.01&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>13.41±0.03&lt;sup&gt;c&lt;/sup&gt;</td>
<td>12.95±0.02&lt;sup&gt;d&lt;/sup&gt;</td>
<td>15.17±0.04&lt;sup&gt;b&lt;/sup&gt;</td>
<td>21.43±0.03&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Emulsification capacity (ml oil/g sample)</td>
<td>18.56±0.03&lt;sup&gt;d&lt;/sup&gt;</td>
<td>25.12±0.04&lt;sup&gt;b&lt;/sup&gt;</td>
<td>19.32±0.02&lt;sup&gt;c&lt;/sup&gt;</td>
<td>17.82±0.03&lt;sup&gt;c&lt;/sup&gt;</td>
<td>24.45±0.04&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>*</sup>n=3, Results are expressed as mean values ± standard deviations. Means in a row with different superscripts are significantly different (P<0.05)

Incorporation of germinated brown rice and pearl millet lowered the gelling strength of blends (Obalolu and Cole, 2000). Trough viscosity is the maximum attainable viscosity at constant temperature phase. It analyzed the ability of flour to withstand break down of starch molecules during cooling. Corresponding to peak viscosities, similar pattern for trough
viscosity was observed. Higher trough viscosity (cP) was observed in control sample (861.00±0.41 cP). Legume blends of both wheat and triticale based combinations were observed with trough viscosity of 495.00±0.38 cP and 541.00±0.34 cP respectively. Triticale based cereal blend exhibited lower value of trough viscosity as compared to control and legume blends which was observed as 352.00±0.42 and closely followed by wheat based cereal blended flour (317.00±0.46). The decrease in the viscosity could be attributed to more damaged starch molecules in flour due to activation of hydrolyzing enzymes during germination (Batey and Curtin, 2000).

Breakdown is the measure of stability of starch or flour. At this stage the swollen molecules started to disintegrate. Breakdown thus measured the pasting and thermal stability of flour or starch. Lower the value of breakdown more is the thermal and pasting stability. Breakdown value of wheat based cereal blend was lower among all the analyzed flour combinations (12.00±0.35 cP). Whereas control flour sample exhibited higher breakdown value (67.00±0.51 cP). The value of breakdown for wheat based legume fortified, triticale based cereal and legume fortified flour were observed as 24.00±0.43, 21.00±0.45 and 40.00±0.42 cP respectively.

Final viscosity is the index of material’s ability to form viscous paste. Final viscosity of control sample was quite high as compared to blended flours (1124.00±0.43). Blending of flours in wheat and triticale lowered the value of final viscosity. Corresponding to peak viscosity and trough viscosity, final viscosity followed the same pattern. Final viscosity (cP) of legume blended flours of wheat (934.00±0.44 cP) and triticale (975.00±0.49 cP) were reported higher as compared to cereal blends of wheat (510.00±0.49 cP) and triticale (541.00±0.52 cP).
Setback referred to the tendency of flour retrogradation during cooling phase of RVA cycle. Higher setback viscosity corresponds to lower retrogradation tendency (Kesarwani et al., 2016). Setback viscosity of legume based blends was reported higher than control and cereal blends. Setback viscosity (cP) of wheat based legume blend was 439.00±0.52 cP followed by legume blend of triticale which was reported as 434.00±0.47 cP. Control sample was observed with setback viscosity of 263.00±0.38. Values of setback viscosity (cP) in cereal blend of wheat (193.00±0.44 cP) was lower as compared to control, followed by triticale based cereal blends (189.00±0.46 cP). Higher value of setback viscosity could also related to staling rate of product i.e. higher setback viscosity, lower would be its staling rate (Adeyemi and Idowu, 1990).

Pasting temperature corresponded to the presence or absence of starch which is resistant to swelling, its ability of molecules to bind water and is a measure of gelatinization tendency. Cereal blends of both wheat and triticale were observed with higher value of pasting temperature °C which were reported as 90.50±0.14 °C and 91.25±0.18 °C respectively. Pasting temperature (°C) of control sample followed the cereal blends and was reported as 88.20±0.12. Legume blend of wheat and triticale were observed lower for the value of pasting temperature (°C) which were reported as 83.85±0.17 and 82.40±0.14 respectively (Morris et al., 1997).

Peak time provides the information regarding minimum time for flour to cook. Legume containing blends required lesser time to cook. Peak time for both blends was reported as 5.67 min, which was slightly lesser than cereal blends. Cereal blended with wheat required 6.13±0.11 min., whereas combination of cereal blended with triticale required 6.27±0.15 for the flour to cook. Control sample was observed with higher value of peak time which was reported as 6.87±0.09 min. Blending of flours with different composition allowed
interaction of molecules therefore difference in cooking time was obtained as a result (Abedowale et al., 2012).

Viscosity not only depends on the starch content and its constituents solely, therefore while considering flours other factors like dietary fibers (Dikeman et al., 2006) were also associated with starch molecules and thus affected the viscosity of blended flours.

9.3.3. Characterization of prepared cookies

9.3.3.1. Chemical analysis of cookies prepared from optimized blends

Cookies prepared from optimized blends were analyzed for their nutritional characteristics along with control as shown in Table 9.3. Legume and cereals were blended in wheat and triticale bases to develop novel formulation products (cookies). Legume blended cookies having both wheat and triticale bases contained higher amount of protein, fats, ash and crude fiber due to composition of legumes.

Different cookies were compared with control sample which were prepared from raw wheat and observed differences in compositional characteristics. Moisture content of control sample was lower whereas cookies with legume blended in triticale flour were observed with higher moisture content followed by legume blended wheat cookies. Cereal blended cookies were observed with lower moisture content than legume blended cookies but higher than control sample. The moisture content of wheat and triticale based cookies was 4.23±0.03%, 4.16±0.01% respectively. Whereas, wheat and triticale based legume blended cookies were observed with moisture content of 4.89±0.01% and 5.23±0.02% respectively. This could be attributed to the higher protein content in legume fortified cookies (Mustafa et al., 1986) which tended to absorb more moisture content. Legume fortified wheat cookies contained higher protein content of 12.32±0.11 g/100g sample, followed by legume fortified triticale cookies which exhibited the protein content of 11.81±0.05 g/100g sample.
Table 9.2. Pasting properties of control and optimized flour blends

<table>
<thead>
<tr>
<th>Samples</th>
<th>Peak viscosity (cP)</th>
<th>Trough viscosity (cP)</th>
<th>Break down (cP)</th>
<th>Final viscosity (cP)</th>
<th>Set back (cP)</th>
<th>Pasting temperature (°C)</th>
<th>Peak time (Min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control sample</td>
<td>928.00±0.34&lt;sup&gt;a&lt;/sup&gt;</td>
<td>861.00±0.41&lt;sup&gt;a&lt;/sup&gt;</td>
<td>67.00±0.51&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1124.00±0.43&lt;sup&gt;a&lt;/sup&gt;</td>
<td>263.00±0.38&lt;sup&gt;c&lt;/sup&gt;</td>
<td>88.20±0.12&lt;sup&gt;c&lt;/sup&gt;</td>
<td>6.87±0.09&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Wheat based cereal fortified</td>
<td>329.00±0.54&lt;sup&gt;e&lt;/sup&gt;</td>
<td>317.00±0.46&lt;sup&gt;e&lt;/sup&gt;</td>
<td>12.00±0.35&lt;sup&gt;e&lt;/sup&gt;</td>
<td>510.00±0.49&lt;sup&gt;e&lt;/sup&gt;</td>
<td>193.00±0.44&lt;sup&gt;d&lt;/sup&gt;</td>
<td>90.50±0.14&lt;sup&gt;b&lt;/sup&gt;</td>
<td>6.13±0.11&lt;sup&gt;cb&lt;/sup&gt;</td>
</tr>
<tr>
<td>Wheat based legume fortified</td>
<td>519.00±0.47&lt;sup&gt;c&lt;/sup&gt;</td>
<td>495.00±0.38&lt;sup&gt;c&lt;/sup&gt;</td>
<td>24.00±0.43&lt;sup&gt;c&lt;/sup&gt;</td>
<td>934.00±0.44&lt;sup&gt;c&lt;/sup&gt;</td>
<td>439.00±0.52&lt;sup&gt;b&lt;/sup&gt;</td>
<td>83.85±0.17&lt;sup&gt;d&lt;/sup&gt;</td>
<td>5.67±0.12&lt;sup&gt;de&lt;/sup&gt;</td>
</tr>
<tr>
<td>Triticale based cereal fortified</td>
<td>373.00±0.42&lt;sup&gt;d&lt;/sup&gt;</td>
<td>352.00±0.42&lt;sup&gt;d&lt;/sup&gt;</td>
<td>21.00±0.45&lt;sup&gt;d&lt;/sup&gt;</td>
<td>541.00±0.52&lt;sup&gt;d&lt;/sup&gt;</td>
<td>189.00±0.46&lt;sup&gt;e&lt;/sup&gt;</td>
<td>91.25±0.18&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.27±0.15&lt;sup&gt;bc&lt;/sup&gt;</td>
</tr>
<tr>
<td>Triticale based legume fortified</td>
<td>581.00±0.44&lt;sup&gt;b&lt;/sup&gt;</td>
<td>541.00±0.34&lt;sup&gt;b&lt;/sup&gt;</td>
<td>40.00±0.42&lt;sup&gt;b&lt;/sup&gt;</td>
<td>975.00±0.49&lt;sup&gt;b&lt;/sup&gt;</td>
<td>434.00±0.47&lt;sup&gt;a&lt;/sup&gt;</td>
<td>82.40±0.14&lt;sup&gt;d&lt;/sup&gt;</td>
<td>5.67±0.13&lt;sup&gt;ed&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

*<sup>n=3</sup>, Results are expressed as mean values ± standard deviations. Means in a row with different superscripts are significantly different (P<0.05)
Cereal blended cookies were slightly lower in protein as compared to legume blended cookies and values were observed as 9.24±0.33 and 9.36±0.09 g/100g sample for cereal blended wheat cookies and cereal blended triticale cookies respectively. Elin et al. (2003) observed similar findings for fortification of wheat biscuits with germinated chickpea. The increase in the protein content of blended cookies as compared to control could be attributed to higher protein in germinated flours.

Carbohydrate content of control sample was higher as compared to blended cookies. The lower amount of carbohydrate could be attributed to degradation of carbohydrates during germination by the action of hydrolyzing enzymes (Ohtsubo et al., 2005; Vidal-Valverde et al., 2002). Total carbohydrate content of control sample was 69.75±0.47 g/100g sample. Wheat based blends contained carbohydrate in the range of 54.43±0.42 g/100g to 52.32±0.17 g/100g, whereas triticale based blends were found slightly lower and ranged from 49.53±0.39 g/100g to 48.54±0.32 g/100g.

Germination enhanced the capacity of flour to retain more oil (Chimela et al., 2009). Fats content of control sample was lower as compared to blends. Wheat based legume fortified cookies were observed with higher fats content (22.57±0.23 g/100g) followed by triticale based legume fortified cookies (21.54±0.21 g/100g). Cereal blends contained higher fats content than control sample but slightly lower than legume blends. Of the cereal blends triticale based cereal fortified cookies were observed with higher fat content and ranged as 19.82±0.11 compared to 19.73±0.02 g/100g in wheat based cereal fortified cookies. Oil absorption capacity is a function of fat binding non-polar side chains of protein and was affected by number of hydrophobic sites and protein-lipid-carbohydrate interactions (Sibain et al., 2017). Another reason of retention of higher fat was the addition of more fats as shortening to make dough suitable for rolling into cookies. Kidney
bean, pearl millet, brown rice and chickpea are not good in its elastic properties thus cannot be easily rolled into cookies. With the addition of these flours in blends, more shortening in form of oil was required. Due to high protein content more oil was absorbed in blended flours as compared to control (Kinsella et al., 1982).

Crude fiber content of blends was reported higher as compared to control sample. Crude fiber of raw wheat flour cookies was reported as 1.93±0.03 g/100g. Germination increased the crude fiber content of flours and therefore more fiber content was observed as a result in blended cookies. Crude fiber contents of triticale based legume fortified cookies and wheat based legume fortified cookies were highest and reported as 5.79±0.02 and 5.64±0.02 g/100g sample, respectively. Cereal blends were reported with crude fiber content of 3.73±0.0g for cereal fortified wheat cookies and 3.64±0.05g for cereal fortified triticale cookies per 100g sample.

Ash content of control sample was found comparable to cereal blends of wheat and triticale, whereas higher ash content was observed in legume blends of wheat and triticale. Ash content of cereal fortified wheat was lower of all the reported samples. Elin et al. (2004) reported similar observation when refined wheat flour was blended with chickpea flour.

Table 9.3. Chemical analysis of optimized cereal and legume based cookies

<table>
<thead>
<tr>
<th>Characteristic (%)</th>
<th>Legume based cookies</th>
<th>Cereal based cookies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control sample</td>
<td>Wheat</td>
</tr>
<tr>
<td>Moisture</td>
<td>3.57±0.01e</td>
<td>4.89±0.01b</td>
</tr>
<tr>
<td>Protein</td>
<td>07.84±0.02e</td>
<td>12.32±0.11a</td>
</tr>
<tr>
<td>Carbohydrates</td>
<td>69.75±0.47a</td>
<td>54.43±0.42b</td>
</tr>
<tr>
<td>Fats</td>
<td>18.34±0.26c</td>
<td>22.57±0.23a</td>
</tr>
<tr>
<td>Crude fiber</td>
<td>1.93±0.03e</td>
<td>5.64±0.02ba</td>
</tr>
<tr>
<td>Ash</td>
<td>0.82±0.02e</td>
<td>1.43±0.02a</td>
</tr>
</tbody>
</table>

*n=3, Results are expressed as mean values ± standard deviations. Means in a row with different superscripts are significantly different (P<0.05)
9.3.3.2. Textural properties of optimized cereal and legume based cookies

Optimized formulations of cereal and legume based blends of wheat and triticale prepared into cookies were subjected to texture profile analysis for the evaluation of different parameters of texture like hardness, fracturability and chewiness as shown in Table 9.4. Hardness of control cookies sample prepared from raw wheat flour was reported higher and was closely followed by cereal fortified blends of wheat and triticale. The hardness in control cookies sample was found as 62.71±0.05 N and those of cereal blends of wheat and triticale were 58.34±0.03 N and 58.97±0.02 N. Hardness of legume based cookies were observed lower and were observed as 44.56±0.05 N for wheat and 41.80±0.04 N for triticale bases. Hardness as a texture property is considered as measure of freshness of product (Karaoğlu and Kotancilar, 2009) which depends on the moisture distribution between the components of product (Pereira et al., 2013). Other inherent factors like amylose and amylopectin’s re-crystallization also affected the bonding between starch and protein fractions (Seyhun et al., 2003). Components of blend and their interactions affected the hardness of products. Chung et al. (2014) and Chauhan et al. (2015) reported the variation in hardness after blending of native flour with other flours.

Fracturability in texture profile analyzer is the force on first compression force at product. Fracturability is also considered as a measure of brittleness of product. Brittleness of control sample was found higher 7.134±0.03 N followed by cereal fortified, wheat and triticale based cookies having values of 6.192±0.02 N and 6.154±0.03 N, respectively. Fracturability was lower in legume fortified cookies which were found as 5.785±0.03 N in wheat based legume fortified cookies and followed by triticale based legume fortified cookies (4.982±0.04). Distribution of moisture to the outer surface could reduce the fracturability of product. Starch-protein interaction
could be responsible for the textural properties of baked product, whereas distribution of moisture and fat could be the other factors which affected the textural behavior of product.

Cohesiveness is the measure of ability of material to disintegrate and fragility of product which corresponds to the inherent strength of bonds (Abbas et al., 2006; Szczesniak et al., 1975). Cohesiveness in texture profile analyzer was estimated as ratio of areas between second and first compression. Cohesiveness of control sample was higher and reported as 0.724±0.04. Values of cohesiveness for cereal based cookies of wheat and triticale were reported as 0.649±0.02 and 0.621±0.03 respectively. Values of cohesiveness for legume based cookies of wheat and triticale blends were lower than the cereal based cookies and were reported as 0.587±0.01 and 0.501±0.01, respectively. Higher cohesion value corresponded to higher break strength which could be affected by loss of intermolecular attractions during aging (Karaoğlu and Kotancilar, 2009) or moisture retention.

Table 9.4. Texture profile analysis of optimized cereal and legume based cookies

<table>
<thead>
<tr>
<th>Cookies formulations</th>
<th>Hardness (N)</th>
<th>Fracturability (N)</th>
<th>Cohesiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control sample</td>
<td>62.71±0.05</td>
<td>7.134±0.03</td>
<td>0.724±0.04</td>
</tr>
<tr>
<td>Wheat based cereal fortified</td>
<td>58.60±0.03</td>
<td>6.192±0.02</td>
<td>0.649±0.02</td>
</tr>
<tr>
<td>Wheat based legume fortified</td>
<td>41.98±0.05</td>
<td>5.785±0.03</td>
<td>0.587±0.01</td>
</tr>
<tr>
<td>Triticale based cereal fortified</td>
<td>46.21±0.02</td>
<td>6.154±0.03</td>
<td>0.621±0.03</td>
</tr>
<tr>
<td>Triticale based legume fortified</td>
<td>59.76±0.04</td>
<td>4.982±0.04</td>
<td>0.501±0.01</td>
</tr>
</tbody>
</table>

*n=3, Results are expressed as mean values ± standard deviations. Means in a column with different superscripts are significantly different (P<0.05)
9.3.3.3. Color characteristic of formulated cookies prepared from optimized blends

Color measurement acted as another quality criteria to observe the quality of final formulation on the technical scale of $L^*$, $a^*$ and $b^*$ (Table 9.5). Lightness ($L$) of the product prepared from blend of flour decreased as $L^*$ value decreased with flour fortification. $L^*$ value of control cookies prepared from raw wheat flour was higher as compared to cookies prepared from blended flour. Cereal based blends became darker due to the color characteristics of brown rice and pearl millet flour which themselves were slightly dark in color. Decrease in lightness of legume based formulations could be attributed to certain chemical reactions especially maillard reaction which took place at high baking temperature (Chevallier et al., 2000).

$a^*$ and $b^*$ values contributed to red and yellow tone of product and were increased with the blending of flour. Control sample was lower in both redness and yellowish tone having $a^*$ and $b^*$ values of 5.82±0.03 and 25.67±0.04, respectively. Wheat based legume fortified cookies were reported with higher $a^*$ value whereas $b^*$ value was highest in triticale based legume fortified cookies, which could be attributed to its higher protein content. For cereal fortified formulations $a^*$ and $b^*$ values were observed as 7.36±0.04; 29.43±0.06 for wheat and 8.22±0.03; 29.73±0.09 for triticale based products.

On contrary to cereal blends, legume blended flours were observed with higher values of $a^*$ and $b^*$. The values for $a^*$ and $b^*$ for legume blends were observed as 9.13±0.04; 30.84±0.05 for wheat base and 8.42±0.02; 31.17±0.08 for triticale based cookies. Degree of variation of $a^*$ and $b^*$ value could be detrimental for monitoring the browning of formulated product. The mixing of different flours significantly influence the baked products (Choi et al., 2012).
Table 9.5. Color characteristic of cookies prepared from optimized composite flours

<table>
<thead>
<tr>
<th>Cookies formulations</th>
<th>Hunter color values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( L^* )</td>
</tr>
<tr>
<td>Control sample</td>
<td>67.54±0.07(^a)</td>
</tr>
<tr>
<td>Wheat based cereal fortified</td>
<td>49.83±0.03(^d)</td>
</tr>
<tr>
<td>Wheat based legume fortified</td>
<td>52.37±0.04(^b)</td>
</tr>
<tr>
<td>Triticale based cereal fortified</td>
<td>48.76±0.09(^ed)</td>
</tr>
<tr>
<td>Triticale based legume fortified</td>
<td>51.69±0.08(^cb)</td>
</tr>
</tbody>
</table>

\(^*n=3\), Results are expressed as mean values ± standard deviations. Means in a column with different superscripts are significantly different (\(P<0.05\))