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# Influence of beetroot powder (*Beta vulgaris* rubra) on the rheological characteristics of wheat flour dough for utilization in bakery products

**MP Ingle and AR Tapre**

**Abstract**
The effect of replacement of wheat flour with beetroot powder at 5, 7, 10, 15 and 20% level on the rheological qualities of prepared dough were studied. Various rheological properties of dough were evaluated using dough testing instruments such as Farinograph, Extensograph and Amylograph. Farinograph analysis indicates that the increased level of addition of beetroot powder significantly decreased the water absorption from 60.2% to 58.3% and mixing tolerance index from 57.5 FU to 37.8 FU while farinograph quality number increased from 74.0 FU to 96.3 FU with increased level of beetroot powder. At 30 min proving time, the replacement of wheat flour with 20% beetroot powder exhibited the highest resistance to extension value i.e. 1161.8 BU while the lowest value i.e. 345.8 BU was recorded for the dough prepared without beetroot powder at 90 min proving time. The significant increase in gelatinization temperature from 88.43 °C to 90.30 °C was recorded with increased level of beetroot powder from 5 to 20%.

**Keywords:** Beetroot, beetroot powder, rheology, farinograph, amylograph, extensograph

## Introduction
Beetroot (*Beta vulgaris* L.) is an important root vegetable which belongs to the *Chenopodiaceae* family and is originated from temperate climate regions of Europe and North Africa. It is also called as garden beet, red beet, table beet or beetroot in North America. *Beta vulgaris* plant is a cool season crop grown best under organic rich, loamy, well-drained soil. In India beetroot is cultivated in Haryana, Uttar Pradesh, Himachal Pradesh, West Bengal and Maharashtra. Beetroot is an underground fleshy taproot from which leaves emerge directly from its top end with long, stem-like petioles. The plant reaches to the height of about 1 to 2 feet from the ground surface.

Beetroots are a rich source of potent antioxidants and minerals including magnesium, sodium and potassium. It also provides B complex vitamins including niacin (B3), Pantothenic acid (B5), Pyridoxine (B6) (Anon. 2007) [3]. Betaine supplements, manufactured as a byproduct of sugar beet processing, are prescribed to lowers potentially toxic levels of homocysteine, a naturally occurring amino acid that can be harmful to blood vessels thereby contributing to the development of heart disease, stroke and peripheral vascular disease. Beetroots are low in calories (about 45 Kcal per 100 g) and have zero cholesterol and a minimum amount of fat. It is also a good source of protein, carbohydrates, calcium, phosphorus and ascorbic acid. Beetroots in raw form are high in folates. Folates are essential in the synthesis of DNA within cells. The incorporation of composite flour into traditional wheat-based food products provided additional nutrients from non-wheat material and improved the nutritional value of the products (De Ruiter, 1978). In the preparation of bakery products, use of beetroot powder with wheat flour may enhance the nutritional value of the prepared products. Wheat flour exhibited the unique bread making characteristics due to the presence of gluten proteins which form a viscoelastic network when mixed with water. The viscoelastic properties of wheat flour dough may g*et al*tered after substitution by other flours which ultimately affects the bakery products making potential.

Prior to utilization of blended flours, full understanding of the rheological behavior of blended flour dough is of great importance from the practical point of view. Dough rheology relates with the baking performance of flours and useful to optimize the dough formulation. Steffe (1996) [24] outlines several areas in the food industry where rheological characterization is useful. These include calculations in process engineering for pipelines, pumps, extruders, mixer, heat exchangers, and other equipment, ingredient functionality evaluation for product development, quality control, relation of food texture data to sensory data, and study of rheological constitutive equations. Since rheometry can reveal so many integral characteristics of a material, it has great potential for the study of wheat flour dough and regulation of dough processing performance. Therefore, the present investigation was undertaken to study the effect of the replacement of wheat flour with beetroot powder on the rheological properties of prepared dough.

**Materials and Methods**

The present research work was carried out in Department of Food Science and Technology, MPKV Rahuri, during 2014-16. Fresh and matured beetroots were procured from the selected farm near Rahuri.

**Processing of beetroot powder**

Fresh beetroots were washed, blanched, peeled and reduced to size (1-3 mm) using sharp knife. These slices were dried in tray dryer at 60-65 °C for about 7-8 hrs. The dried beetroot slices were subjected to grinding in grinder. Then ground material was passed through 60 mesh sieve and packed in HDPE bags, sealed and stored for further use.

**Preparation of flour blends**

Flour blends were prepared using refined wheat flour and beetroot powder in the ratio of 100:0; 95:5; 93:7; 90:10; 85:15; 80:20 are denoted as $T_0$ (Control), $Tb_1$, $Tb_2$, $Tb_3$, $Tb_4$, $Tb_5$ treatments respectively.

**Rheological characteristics of dough**

**Farinograph of dough**

The rheological properties of the dough prepared from wheat flour and beetroot powder blends were measured using the Brabender farinograph method (T150 E make Brabender GHBM and Co. KG. Germany) according to the approved method No. 54-21 of A.A.C.C. (1983) [1].

**Extensograph characteristics**

The dough extensibility was determined by using the Brabender extensograph (T150 E make Brabender GHBM and Co. KG. Germany) according to the standard method of the A.A.C.C. No. 54 – 10 (1983) [1].

**Amylograph of wheat flour and beetroot powder blends**

Gelatinization of wheat flour and beetroot powder blends was determined by using the brabender amylograph (T150 E make Brabender GHBM and Co. KG. Germany) according to the standard method No. 22-10 of A.A.C.C (1983) [1].

**Statistical analysis**

All results were statistically analyzed by using Completely Randomized Design as per the method suggested by Panse and Sukhatme (1967) [18].

**Results and Discussion**

Rheological properties of dough are useful for predicting the quality of product and potential applications of the wheat flour and blended flours. The effect of replacement of wheat flour with beetroot powder at the level of 5, 7, 10, 15 and 20 per cent level on dough mixing properties were measured by Farinograph, Extensograph and Amylograph.

**Farinograph characteristics of dough**

Farinograph characteristics of the prepared dough were studied and the results are depicted in the Table 1 and typical farinograph curves are shown in Fig 1 (a -f).

It is evident that there was significant decrease in water absorption and mixing tolerance index and increase in dough stability and farinograph quality number with increased level of beetroot powder in wheat flour.

For 500 BU at 14% moisture content, the increased level of addition of beetroot powder significantly decreased the water absorption from 60.2% ($T_0$) to 58.3% ($Tb_5$). Decreased in water absorption with increased level of beetroot powder might be due to lower water holding capacity of beetroot powder. Sindhuja *et al.*, (2005) [22] reported that the water absorption of the wheat flour was 60.62% and it ranged between 60.62 and 57.54% with increased level of amaranth flour in the blend for preparation of cookies. Similar results were reported by Sanchez *et al*., (1985) [20].

The dough development time showed positive correlation with the level of beetroot powder. The higher value of dough development time was obtained for the treatment $Tb_5$ (6.0 min) as compared to other treatments and lowest value was observed in the treatment $Tb_1$ (5.1 min). The increased in dough development time might be due to increase in fiber content of beetroot powder owning to dilution and disruption of continuity of gluten. It confirms the earlier findings by Kucerova *et al.*, (2013); Almeida *et al.*, (2010) [2] and Borchani *et al.*, (2011) [4]. Sindhuja *et al.*, (2005) [22] reported that the dough development time was increased from 1.25 to 4.0 min. with increased level of amaranth flour in the blend for preparation of cookies. The values for mixing tolerance index (MTI) were observed to be decreased with increasing level of beetroot powder. Reduction of mixing tolerance index may be observed due to interactions between fiber and gluten (Wang *et al.*, 2002; Bouaziz *et al.*, 2010) [29, 15]. Similar trend was observed by Mathews *et al.*, (1970) [16] after addition of oilseed flours such as cottonseed, peanut, sunflower seed to wheat flour. Kohajdova *et al.*, (2012) [15] reported that with increased level of carrot pomace powder there was decrease in mixing tolerance index.

The farinograph quality number is the point of the curve in which the curve decreases by 30 FU after the maximum (based on middle line of the diagram). It was revealed that addition of beetroot powder increased farinograph quality number.

**Extensograph characteristics of dough**

Extensograph data reveals information about the viscoelastic behaviour of a dough and measure dough extensibility and resistance to extension. Area under the curve is a combination of resistance and extensibility and is related to the absolute level of elastic and viscous component.

Extensograph data for the addition of different levels of beetroot powder is presented in Table 2 and Fig 2 (a-f). Time analysis data indicates that in all the dough prepared with addition of different levels beetroot powder the resistance to extension decreased with the increase in proving time from 30 to 90 min. At all the proving time viz. 30, 60, 90 min, the replacement of wheat flour with 20% beetroot powder showed the highest resistance to extension value i.e. 1161.8 BU, 1123.3BU and 986.8 BU respectively and lowest values were recorded for the dough prepared with only wheat flour. Similar trend was reported by various scientists for the dough prepared with replacement of wheat flour with different fruits and vegetable flour. Sudha *et al.*, (2007) [25] reported that with increased level of apple pomace up to 30% the resistance to extension value increased from 336 to 742 BU. Turksoy *et al.*, (2011) [28] reported that the resistance at constant deformation value increased from 290 to 547 BU or maximum resistance from 343 to 558 BU with the increased in black carrot fiber content up to 15%. The increase in resistance to extension may be either due to the dilution of gluten proteins or interactions between polysaccharides and proteins from wheat flour as reported by Chen *et al.*, (1988) [6].

Extensibility indicates elasticity of the dough which significantly effects on quality of finished goods. Results depicted in Table 2 indicates that with increased level of beetroot powder the extensibility of the prepared dough was significantly decreased. Dough without beetroot powder recorded highest values of extensibility at all proving time compared to the dough developed with addition of different levels of beetroot powder. This may be either due to the dilution of gluten proteins or interactions between polysaccharides and proteins from wheat flour as reported by Chen *et al.*, (1988) [6]. Gluten has viscoelastic behaviour in which gliadin fraction represents viscous behaviour and glutenin fraction represents elastic behaviour due to difference in molecular size of these fractions (Tsiami *et al.*, 1997; Spies, 1997; Edwards *et al.*, 2001) [27, 23, 9]. Hydration plays major role in modification of protein structure in dough (Gras *et al.*, 2000) [11]. The amount of wheat flour in composite dough altered the properties of polymeric protein structure of dough which was effective on extensibility. Also change in resistance to extension could be related to the presence of enzymes such as amylases, xylanses, pillulanses, laccases, arabinases, etc., which have an effect on dough resistance and extensibility (Indrani *et al.*, 2003; Selinheimo *et al.*, 2006) [12, 6]. The results of the present investigation are in agreement with previous findings. Sudha *et al.*, (2007) [25] reported that with increase in apple pomace content to 30% the extensibility values decreased from 127 to 51 mm. Turksoy *et al.*, (2011) [28] observed that the extensibility value decreased from 127 to 84 mm with the increase in black carrot fiber content up to 15%. Mathews *et al.*, (1970) [16] stated that dough extensibility decreased when wheat flour was replaced with oilseed flour. Dervas *et al.*, (1999) [7] reported decreased extensibility as the substituted level of lupin flour increased from 5–15%.

**Amylograph characteristics of dough**

Starch functionalities are very often decisive for rheological properties of foods. The properties of starches at high temperatures were examined by Brabender Amylograph and the results are presented in Table 3 and Fig 3(a-f). The pasting profiles help in understanding the potential relationships between the structural features of the starch molecules and their effects on more than one kind of functional behaviour.

Results indicated that there was significant increase in beginning of gelatinization temperature with increased level of beetroot powder from 5% to 20%. The difference in pasting temperature may be because of varying gelation temperatures of the fiber fractions present in beetroot powder by Naruenartwongsakul *et al.*, (2004) [17] The effect of gelatinization on dough rheological properties was mainly because of temperature on gluten (Gelians and Mckinnon, 2004) [10]. Pasting temperature (PT) is the first deflection of temperature in amylogram, where the curve begins to rise (Rasper, 1980) [19]. Sudha *et al.*, (2007) [25] reported that the pasting temperature was increased from 60 to 63 °C with increase in apple pomace content from 0% to 15%. Drisya *et al.*, (2015) [8] also observed the same trend in pasting temperature.

The significant increase in gelatinization temperature was observed with increased level of beetroot powder from 5 to 20%. It was found to be increased from 88.43 °C ($T_0$) to 90.30 °C ($Tb_5$). Starch granule size and structure, amylose/amylopectin ratio and molecular weight influenced the pasting properties of flours (Thomas and Atwell, 1999). The pasting properties of starch were considered to be affected by its amylose content and chain length distribution of amylopectin (Jane *et al.*, 1999) [13]. Sudha *et al.*, (2007) [25] reported that pasting characteristics of wheat flour blended with varying levels of dried leaves (DL) showed that there was marginal increase in gelatinization temperature from 65.6 to 67.4 °C. Viscosity values were observed to be increased with increase in beetroot powder level. Dough prepared with 20% beetroot powder recorded the highest viscosity value 1310.75 AU.

**Table 1:** Effect of addition of different levels of beetroot powder on farinograph characteristics of dough

| Treatments* | Water absorption (for 500 FU) (%) | Water absorption (for 14% moisture) (%) | Dough development time (min) | Mixing tolerance index (FU) | Farinograph quality number (FU) |
|---|---|---|---|---|---|
| $T_0$ | 60.2 | 60.2 | 5.3 | 57.5 | 74.0 |
| $Tb_1$ | 61.1 | 61.2 | 5.1 | 65.8 | 74.8 |
| $Tb_2$ | 60.1 | 60.1 | 5.2 | 64.0 | 75.3 |
| $Tb_3$ | 59.7 | 59.7 | 5.2 | 59.8 | 78.0 |
| $Tb_4$ | 58.8 | 58.8 | 5.5 | 53.0 | 87.8 |
| $Tb_5$ | 58.3 | 58.3 | 6.0 | 37.8 | 96.3 |
| SE ± | 0.065 | 0.053 | 0.051 | 0.659 | 0.456 |
| CD at 5% | 0.192 | 0.159 | 0.153 | 1.957 | 1.356 |

* $T_0$= Control, $Tb_1$=5%, $Tb_2$=7%, $Tb_3$=10%, $Tb_4$=15%, $Tb_5$=20% beetroot powder.

**Table 2:** Effect of addition of different levels of beetroot powder on resistance to extension and extensibility

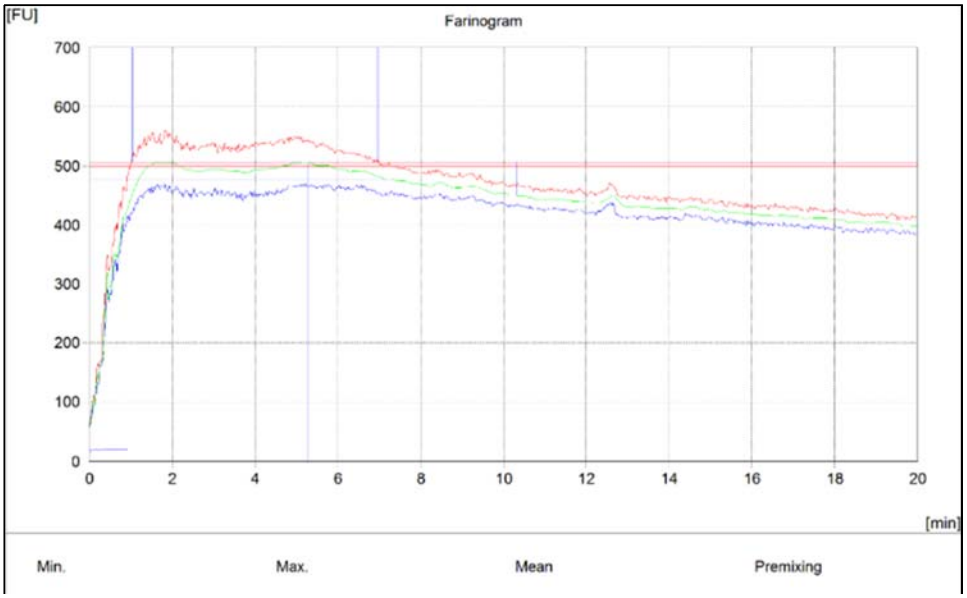
| Treatments* | Resistance to extension (BU) | | | Extensibility (mm) | | |
|---|---|---|---|---|---|---|
| | 30 | 60 | 90 | 30 | 60 | 90 |
| $T_0$ | 439.3 | 386.3 | 345.8 | 135.0 | 148.8 | 164.5 |
| $Tb_1$ | 461.0 | 437.3 | 404.3 | 134.3 | 140.5 | 146.5 |
| $Tb_2$ | 548.0 | 472.8 | 429.5 | 127.3 | 128.3 | 137.5 |
| $Tb_3$ | 526.3 | 526.3 | 493.0 | 124.0 | 125.3 | 125.8 |
| $Tb_4$ | 933.3 | 792.8 | 736.3 | 96.3 | 102.5 | 102.8 |
| $Tb_5$ | 1161.8 | 1123.3 | 986.8 | 74.3 | 86.8 | 94.3 |
| SE ± | 1.538 | 1.228 | 1.667 | 0.842 | 1.184 | 1.497 |
| CD at 5% | 4.569 | 3.647 | 4.952 | 2.501 | 3.519 | 4.446 |

* $T_0$= Control, $Tb_1$=5%, $Tb_2$=7%, $Tb_3$=10%, $Tb_4$=15%, $Tb_5$=20% beetroot powder.

**Table 3:** Effect of addition of different levels of beetroot powder on amylograph characteristics of dough

| Treatments* | Beginning of Gelatinization (°C) | Gelatinization Temperature (°C) | Gelatinization Maximum (AU) |
|---|---|---|---|
| $T_0$ | 59.10 | 88.43 | 1207.75 |
| $Tb_1$ | 60.13 | 89.15 | 1205.50 |
| $Tb_2$ | 60.30 | 89.23 | 1215.50 |
| $Tb_3$ | 60.50 | 89.28 | 1226.25 |
| $Tb_4$ | 60.78 | 90.10 | 1275.25 |
| $Tb_5$ | 61.15 | 90.30 | 1310.75 |
| SE± | 0.04 | 0.09 | 2.57 |
| CD at 5% | 0.13 | 0.26 | 7.65 |

* $T_0$= Control, $Tb_1$=5%, $Tb_2$=7%, $Tb_3$=10%, $Tb_4$=15%, $Tb_5$=20% beetroot powder.

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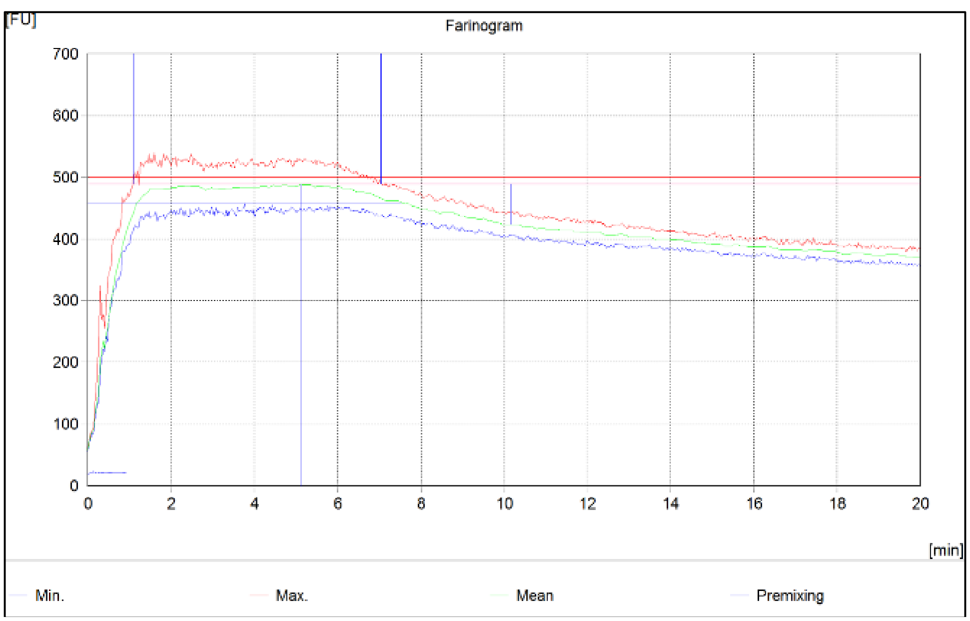


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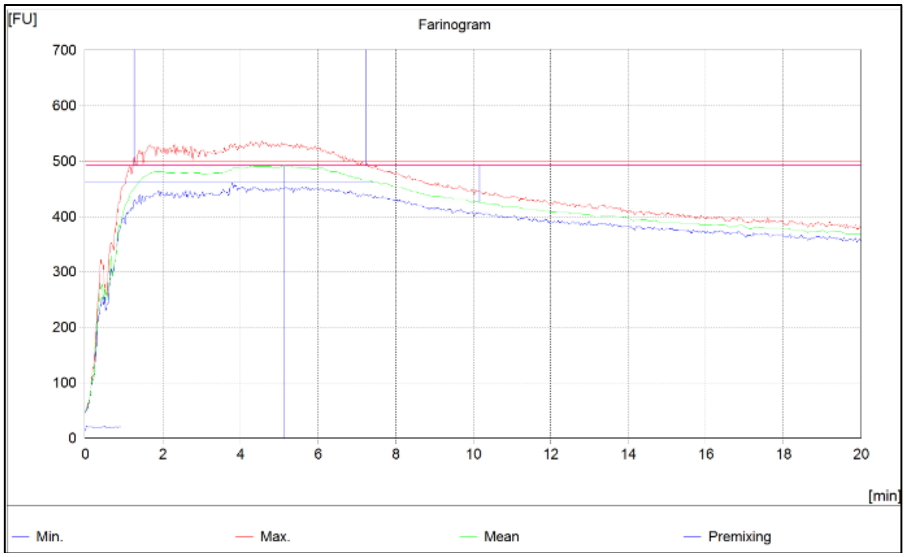
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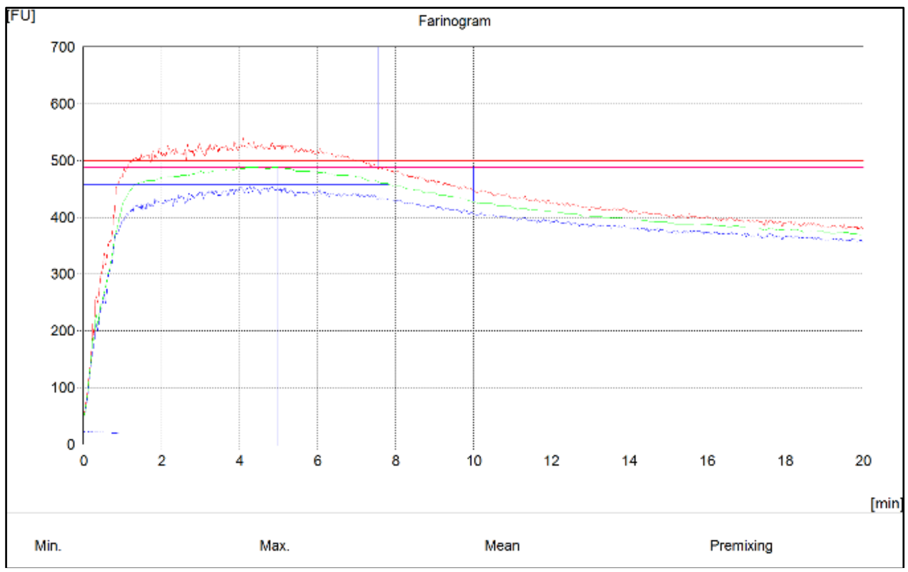
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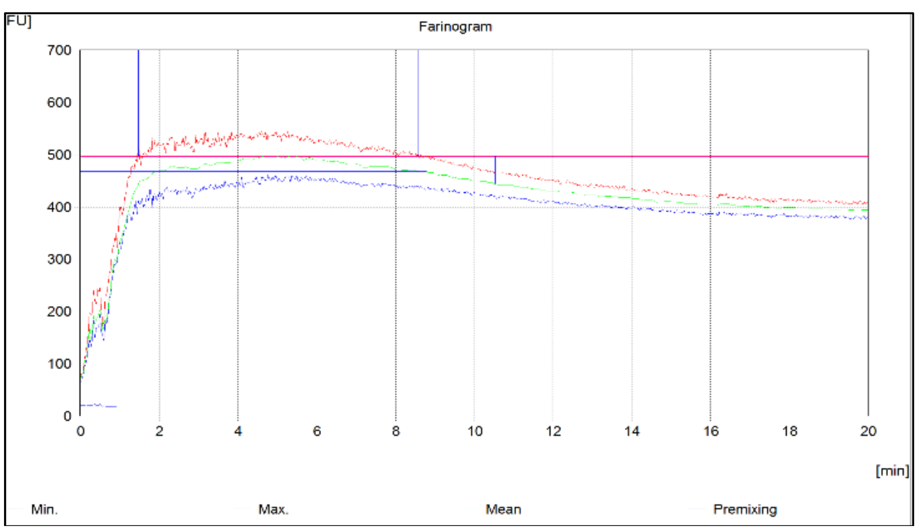
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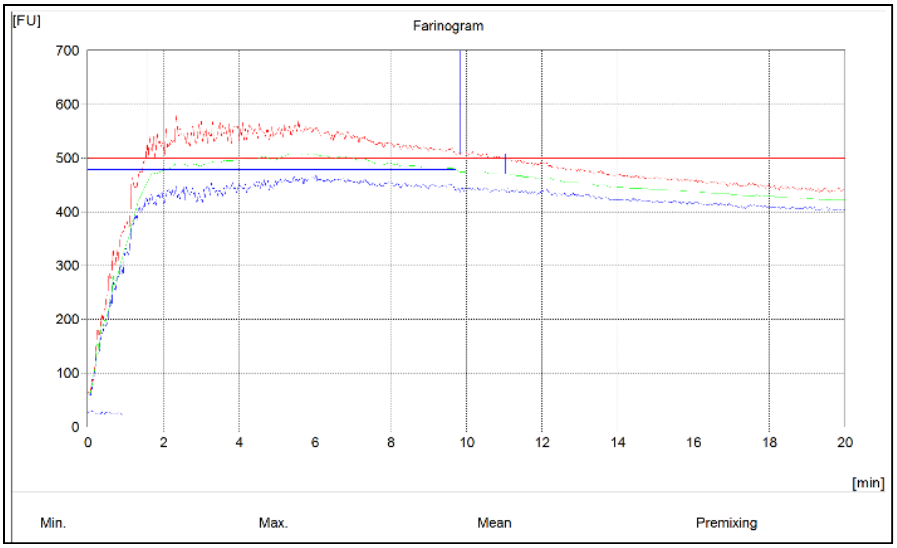
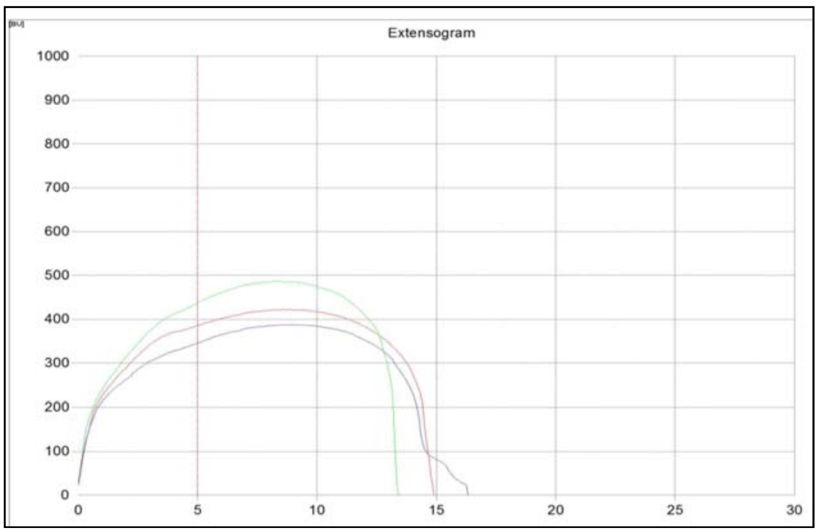



(f)

**Fig 1:** Farinographic characteristics of dough prepared with blends of wheat flour and beetroot powder: a) Control $T_0$ b) $Tb_1$ (95:05) c) $Tb_2$ (93:07) d) $Tb_3$ (90:10) e) $Tb_4$ (85:15) f) $Tb_5$ (80:20)

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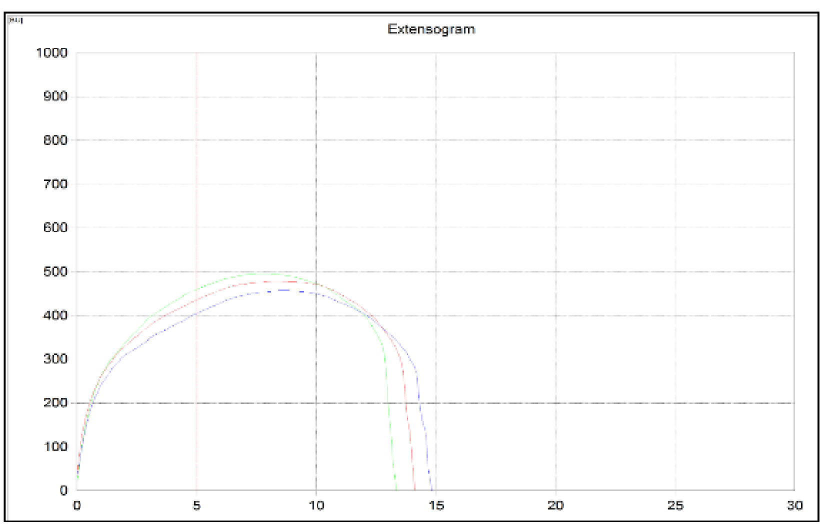


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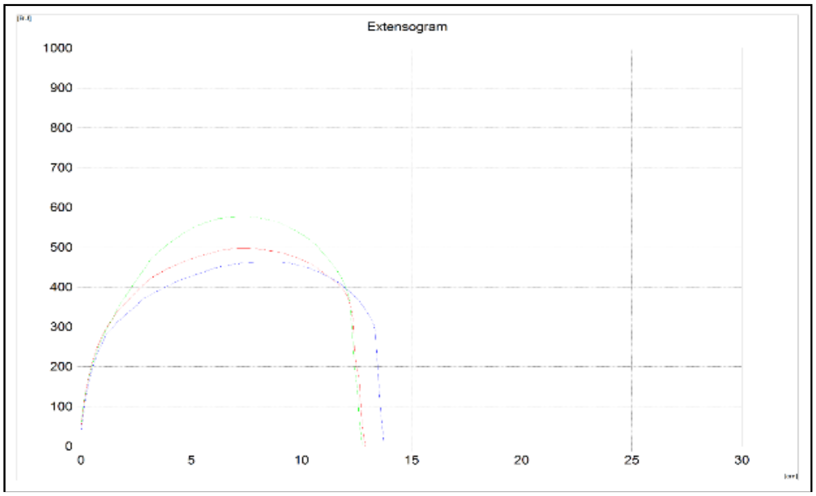
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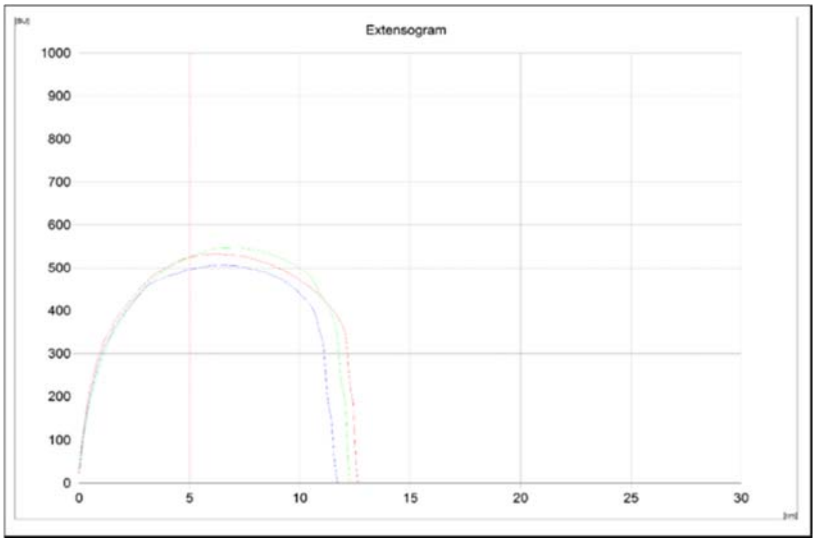
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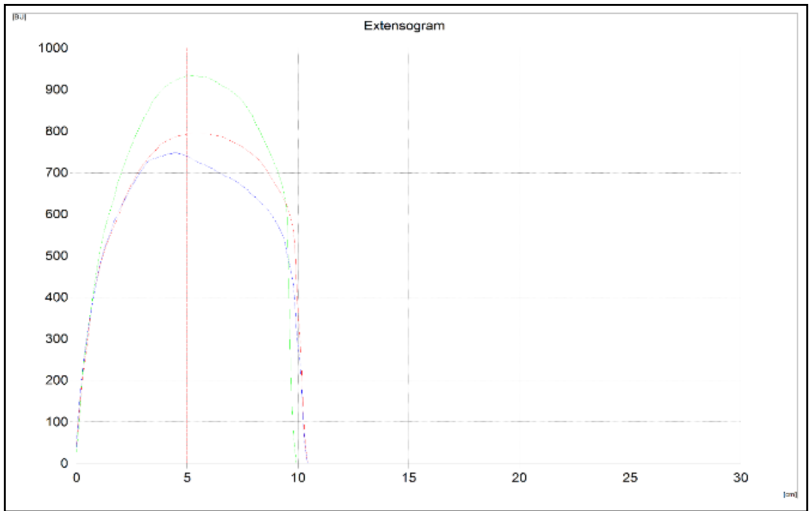
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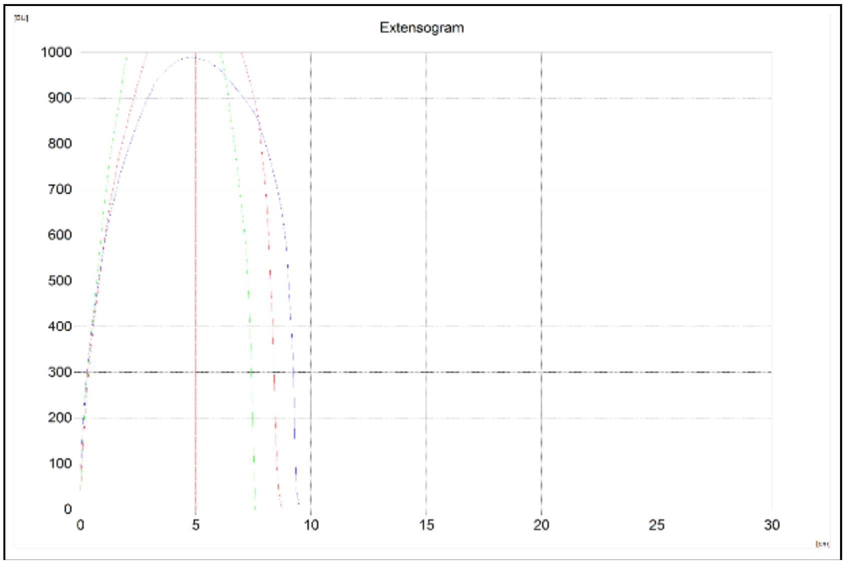
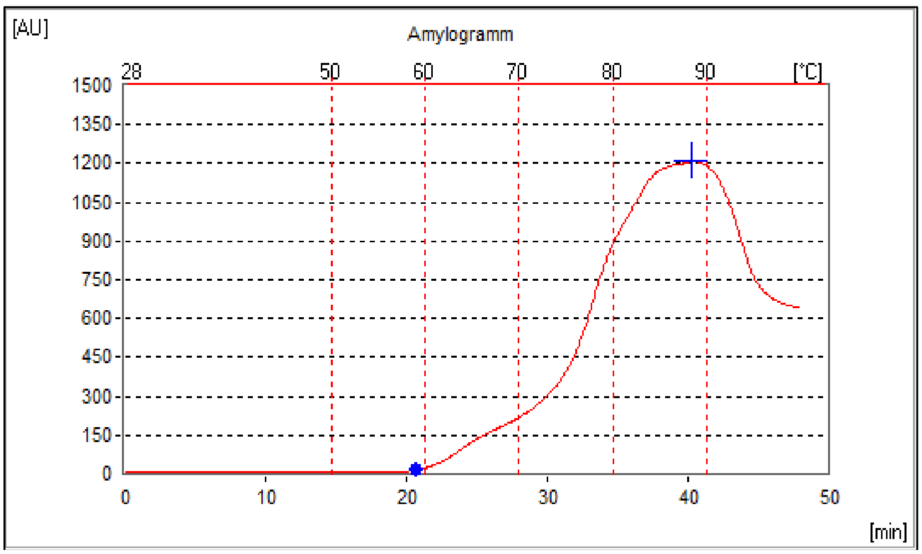



**(f)**

**Fig 2:** Extensographic characteristics of dough prepared with blends of wheat flour and beetroot powder: a) Control $T_0$ b) $Tb_1$ (95:05) c) $Tb_2$ (93:07) d) $Tb_3$ (90:10) e) $Tb_4$ (85:15) f) $Tb_5$ (80:20)

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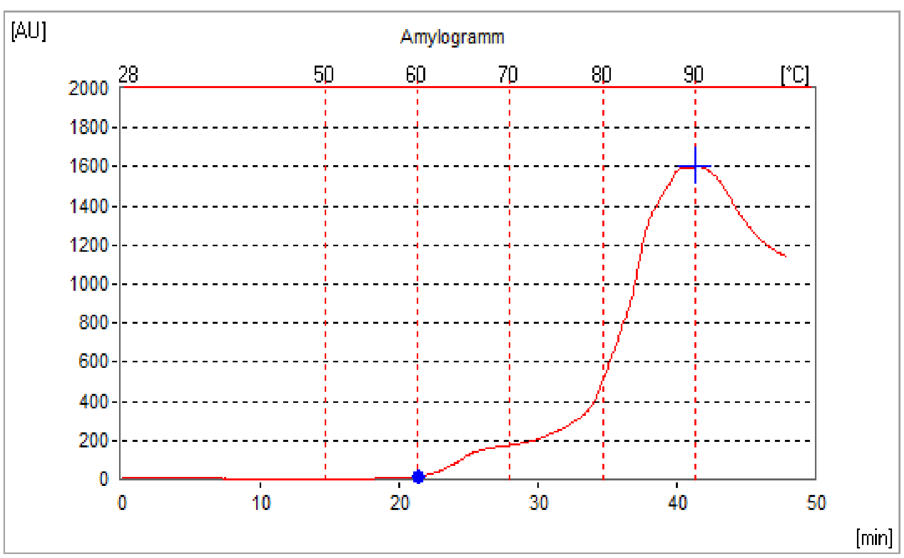


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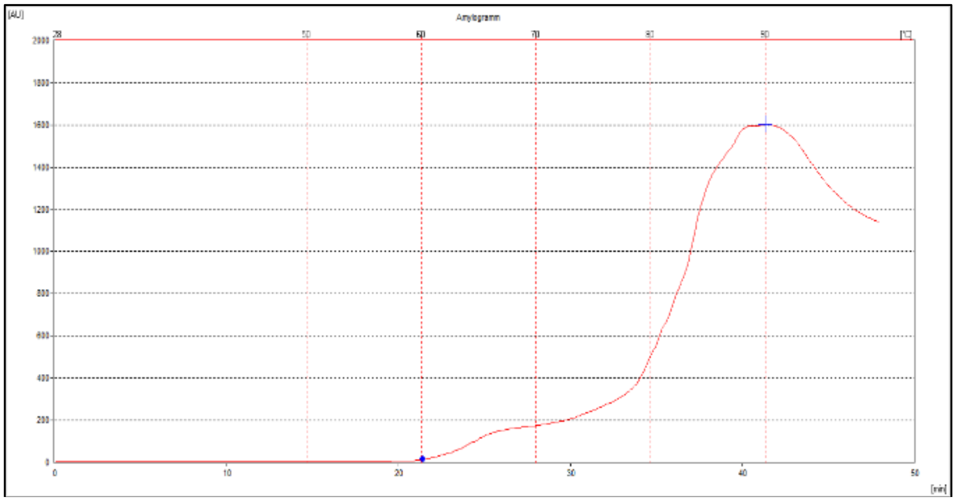

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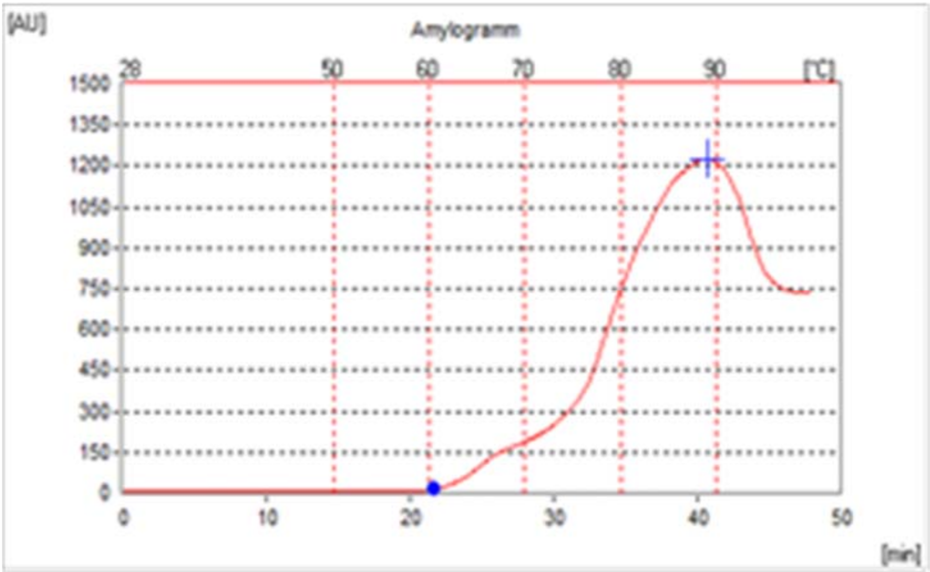
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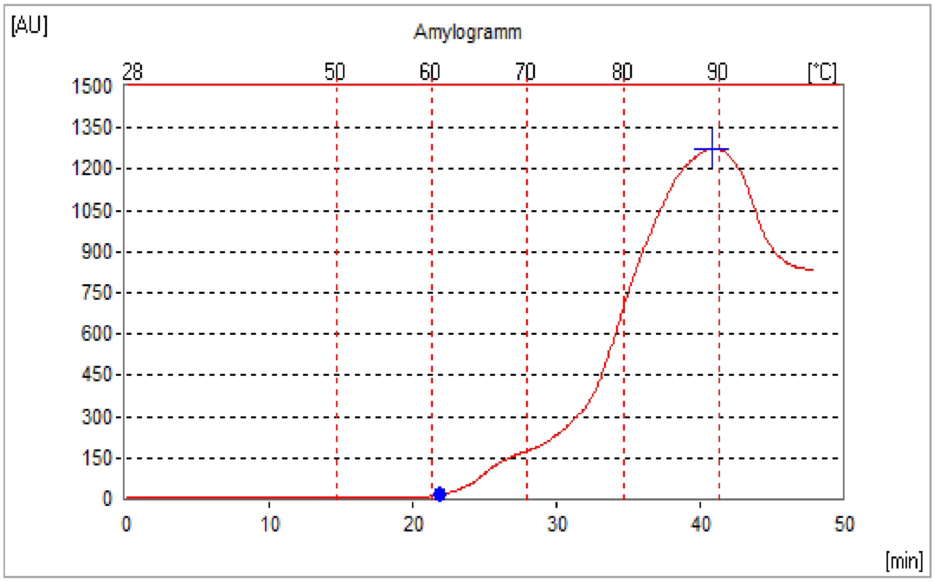
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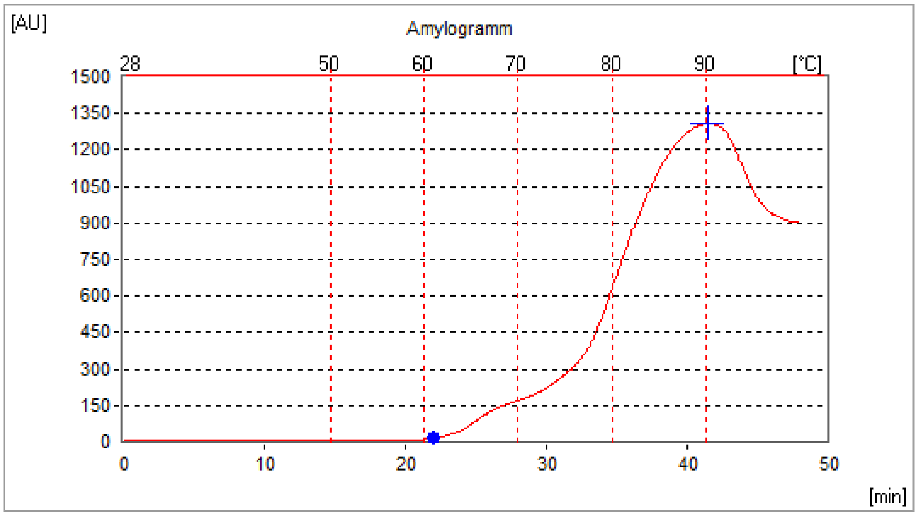


**(f)**

**Fig 3:** Amylographic characteristics of dough prepared with blends of wheat flour and beetroot powder: a) Control $T_0$ b) $Tb_1$ (95:05) c) $Tb_2$ (93:07) d) $Tb_3$ (90:10) e) $Tb_4$ (85:15) f) $Tb_5$ (80:20)

## Conclusion

Characteristics of the dough prepared with replacement of wheat flour with different levels of beetroot powder were investigated to observe the feasibility of nutritious beetroot powder in wheat-based foods. The present study concluded that the increased level of beetroot powder in wheat flour significantly decreased the water absorption and mixing tolerance index whereas increased the dough stability and farinograph quality number. Dough prepared with increased level of beetroot powder offers more resistance to extension thereby the extensibility was significantly decreased with increased level of beetroot powder. Gelatinization temperature of the dough gets increased with increased level of beetroot powder.

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