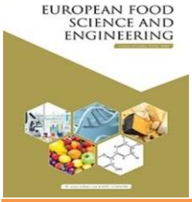

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Effect of oleaster flour addition as a source of dietary fiber on rheological properties of wheat dough

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ABSTRACT

Oleaster (*Elaeagnus angustifolia* L.), is a tree fruit which acclimatizes well even to arid and barren lands and thereby grows in wide geographical regions of Mediterranean and Central Asia and countries such as Turkey, Russia and Kazakhstan. Oleaster fruit is a food, which contains significant amounts of nutraceuticals such as dietary fiber, phenolic acids, carotenoids, vitamins and minerals. In this research, wheat flour (WF) was substituted with oleaster flour (OF) at different concentrations of (0%, 5%, 10% and 15%, w: w) with the aim of dietary fiber enrichment and rheological properties of the WF-OF blend doughs were analyzed. In the case of farinograph findings, water absorption decreased gradually ($P<0.05$) from 57.25% to 51.85% while decrease in stability and dough development by substitution of WF with 5% OF was insignificant ($P>0.05$). Extensograph studies showed that OF substitution significantly ($P>0.05$) increased energy, resistance to extension and maximum resistance values. Extensibility was negatively influenced or unaffected from OF addition at different proving times. In conclusion, especially 5% or 10% addition of OF could be favorable for bread-making based on farinograph and extensograph results. However, influence of OF on properties of the final product should be investigated to fully reveal its convenience in bread-making.

1. Introduction

Bread is one of the oldest processed foods that has been consumed by humanity for ancient times (Cauvain, 2015). Traditionally, bread is produced using wheat flour (WF) besides flours from some other cereals and legumes are also used as raw material. White bread is still the most commonly consumed bread type in Turkey as well as in the World although whole-grain breads are being more popular due to higher abundancy of several nutrients such as vitamins, minerals and dietary fiber as compared to white bread (Agama-Acevedo, Pacheco-Vargas, Gutierrez-Meraz, Tovar, & Bello-Perez, 2019). Main reason for consumer preference of white bread is its favorable organoleptic properties (Mann, Pearce, McKevith, Thielecke, & Seal, 2015).

Consumer demand for healthier food products rich in health-promoting agents including antioxidants, vitamins, minerals, probiotics and dietary fibers have increased for a couple of decades. Dietary fibers are defined as polysaccharides that cannot be hydrolyzed by the digestive enzymes of human, therefore they undergo bacterial fermentation in the gastrointestinal tract and positively influence the intestinal microflora (Holscher, 2017). White bread contains low levels of dietary fiber and high calorie which its high consumption may promote several health problems including obesity and diabetes. Therefore, several approaches such as addition dietary fibers and different protein sources as well as sourdough fermentation technique have been tested in bread-making in order to lower its calorie and/or glycemic index (Belghith Fendri et al., 2016; De Angelis et al., 2009; Marangoni & Poli, 2008; Martin, Chiron, & Issanchou, 2013; D. Sabanis, Lebesi, & Tzia, 2009).

As known, bread manufacture is a highly complex and noteworthy process in which parameters must be optimized in order to produce a high quality bread (Almeida, Chang, & Steel, 2010). Rheological parameters of dough are often measured for prediction of the quality properties of the final product (Kurek & Wyrwisz, 2015). Incorporation of dietary fiber or dietary fiber rich sources into wheat dough can also modify its rheological properties, which has been investigated by several researchers (Ahmed, Almusallam, Al-Salman, AbdulRahman, & Al-Salem, 2013; Huang, Guo, Wang, Ding, & Cui, 2016; Kucerovs, Sottnikova, & Nedomova, 2013; Peressini & Sensidoni, 2009; Ronda, Pérez-Quirce, Angioloni, & Collar, 2013).

Oleaster (*Elaeagnus angustifolia* L) tree, belonging to Elaeagnaceae family, is a bearer plant that can grow in very coarse climatic conditions in many countries including Turkey (Yagmur, Gokce, Tekin, Semerci, & Aktas, 2020). The tree

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can live for long times (80-100 years) and fruits after 5-6 years of planting (Hamidpour et al., 2016). Oleaster fruits have been demonstrated to have high nutritional properties and contain a variety of beneficial compounds such as carbohydrates, protein, phenolics, carotenoids, vitamin A, vitamin C, calcium, magnesium, potassium, iron and manganese (Hassanzadeh & Hassanpour, 2018; Sharifian-Nejad & Shekarchizadeh, 2019). The fruit has also been proven as a rich source of dietary fibers (Sahan et al., 2015) and it is widely used as a dietary component in human and animal diet (Farzaei, Bahramsoltani, Abbasabadi, & Rahimi, 2015). Its inhibitory effect against α-glucosidase and α-amylase enzyme has also been proven (Berktas & Cam, 2020). To the best of our knowledge, oleaster fruit has not been used in any bread formulation as a dietary fiber source. Therefore, this study was conducted to determine the influence of substitution of WF with oleaster flour (OF) at different concentrations on dough's rheological properties. Physical properties of the flour samples were also investigated.

2. Materials and methods

2.1. Materials

Mature oleaster (*Elaeagnus angustifolia* L.) fruits and wheat (*Triticum aestivum*, protein content: 11.9%) flour was kindly provided from Ziya Organik A.S. (Istanbul Turkey) and Istanbul Halk Ekmek (Turkey), respectively. The oleaster fruits were peeled by hand and the seeds were removed. The resulting flesh was finely ground and oleaster flour (OF) was obtained. DPPH (1, 1-diphenyl-2-picrylhydrazyl) and bromophenol blue were purchased from Sigma (Germany) while Folin–Ciocalteu's reagent was provided from Merck (Germany). All other chemicals used were analytical/technical grade.

2.2. Characterization of OF

OF (dietary fiber content of 20.10% (Yavuz, 2019)) was characterized for several physicochemical and bioactive properties. Moisture, ash and protein contents of the flour were determined based on the approved AACC methods 44-15A, 8-01 and 46-12, respectively.

For determination of bioactive properties of the OF, firstly flour extract was obtained by maceration of 5 g of flour in 45 mL of methanol (85% v:v) for 90 min. Then the mixture was centrifuged at 9000 rpm using a homogenizer (Hettich 320R, Germany) and the solvent was evaporated using a rotary evaporator (Hassanpour & Alizadeh, 2016).

Total phenolic content was measured by Folin-Ciocalteu method based on the method described by Singleton, Orthofer, and Lamuela-Raventós (1999). For this purpose, 0.5 mL of the diluted extract was incorporated with Folin reagent (0.2 N) and 2 mL of Na_2CO_3 (7.5% w:v) and incubated at room temperature for 30 min. Then the absorbance of the mixture was measured at 760 nm using a UV-vis spectrophotometer (Shimadzu UV-1800, Japan). The results were expressed as mg gallic acid equivalent (GAE)/g.

In order to determine the antiradical activity of the OF using DPPH radical, 0.1 mL of the diluted extract was incorporated with 50 mL of 0.1 mM DPPH solution in methanol. Then the mixture was left in dark for 30 min and its absorbance was measured 517 nm. Percent antiradical activity (% ARA) was calculated using the following formula:

$$\%ARA = \left(1 - \frac{A_s}{A_c}\right) x100 \quad (1)$$

where A_s and A_c are absorbance values of the extract and control (methanol), respectively.

2.3. Preparation and characterization of the flour mixtures

Four flour mixtures were prepared by substitution of WF with OF at the ratios of 0%, 5%, 10% and 15%. Then the flour mixtures were analyzed for their moisture and ash contents and sedimentation values using the approved AACC methods 44-15A, 8-01 and 56-61.02, respectively. In principle, sedimentation assay measures the sedimented amount of flour slurry treated with lactic acid for 5 min and it is a measure of protein quality and capacity of flour (Montemayor-Mora et al., 2018).

2.4. Determination of rheological properties of the flour mixtures

Behavior of WFs substituted with different levels of the OF during mixing was performed according to AACC approved method 54-22.01 using a 300-g mixer capacity Brabender apparatus (Brabender Inc., Duisburg, Germany) equipped with water dosing. Water absorption (percent amount of water to obtain dough consistency of 500 Brabender units (BU)), stability (time which the dough will keep its initial consistency), development time (time required to form the dough) and degree of softening (BU) parameters were obtained with the farinograms.

Extensograph behaviors of the flour mixtures were analyzed based on the approved AACC method 54-10.01 using a Brabender extensograph (Extensograph-E, Brabender Inc., Duisburg, Germany). Energy (cm^2), resistance to extension (BU), extensibility (mm), maximum resistance (BU), ratio number and maximum ratio number were obtained using the extensograms.

2.5. Statistical analysis

Statistical analysis (analysis of variance – ANOVA) of the experimental data was performed using a statistical analysis software (SAS 9.4; SAS Institute, Cary, North Carolina, USA). Significant differences between the data were analyzed using Tukey multiple comparison test at the significance level of 95%.

3. Results and Discussion

3.1. Characteristics of the OF

Table 1 shows some physical and bioactive properties of the OF. As seen in the table, OF had higher moisture and ash and lower protein contents as compared to a standard white bread flour. Similar moisture and protein contents were reported for peeled and unpeeled OFs (Sahan et al., 2015) while the OF incorporated into ice cream had 88.1% moisture and 2.09% ash levels as given by Çakmakçı et al. (2015).

Different parts of oleaster such as seed, fruit and flowers have been demonstrated to contain phenolic and flavonoids possessing antioxidant activity and protecting body against oxidative hazards (Hamidpour et al., 2016; Saboonchian, Jamei, & Hosseini Sarghein, 2014). In this study, total phenolic content and antiradical (DPPH scavenging) activity of OF were 3957.06 mg GAE/g and 6.48%, respectively (Table 1). Faramarz, Dehghan, and Jahanban-Esfahlan (2015) investigated antioxidant properties of different parts (flesh, peel and seed) of oleaster belonging to various genotypes and found that seeds exhibited the strongest antioxidant property as determined by total phenolic content and radical scavenging activity while activities of flesh and peel was variable.

Table 1. Physicochemical and bioactive properties of the oleaster flour.

Parameter	Result
Moisture (%)	21.96±0.50
Ash (%)	1.85±0.04
Protein content (%)	3.88±0.00
Total phenolic content (mg GAE/g)	3957.06±20.81
Antiradical activity (%)	6.48±0.33

3.2. Physicochemical properties of the flour mixtures

Table 2 shows moisture and ash contents and sedimentation values of WFs substituted with different levels of the OF. Moisture levels of the flour samples varied from 14.21% to 15.64%. Flour mixtures had lower ($P<0.05$) moisture and ash contents with the increasing OF content. Sedimentation assay is an easy and practical method which gives information about protein composition and wheat hardness. Sedimentation value of a WF is highly correlated with its protein content (Hruskova & Famera, 2003). As seen in Table 2, sedimentation values of the flour samples substituted with the OF ranged from 24.03 to 27.53 mL while increasing OF content caused significant ($P<0.05$) reduction in sedimentation values, which is mainly affected by lower protein content of the OF (Table 1). In general, sedimentation values between 25 and 36 mL is belonged to semi-hard WFs having protein content favorable for bread-making. Similar to our findings, Dhingra and Jood (2004) found that incorporation of barley and soybean flours into WF decreased the sedimentation values. Marathe, Machaiah, Rao, Pednekar, and Sudha Rao (2002) reported sedimentation values between 26.2 and 27.4 mL for WF samples irradiated at different doses.

Table 2. Physicochemical properties of the flour mixtures.

Flour	Dry matter (%)	Ash (%)	Sedimentation (%)
WF100	14.21±0.85^{B}	0.78±0.05^{B}	27.53±0.71^{A}
WF95-OF5	14.58±0.14^{BA}	0.83±0.02^{B}	26.53±0.71^{A}
WF90-OF10	15.03±1.04^{A}	0.89±0.11^{BA}	26.53±0.71^{A}
WF85-OF15	15.64±0.95^{A}	0.94±0.15^{A}	24.03±0.00^{B}

WF100: Wheat flour; WF95-OF5: Wheat flour substituted with 5% oleaster; WF90-OF10: Wheat flour substituted with 10% oleaster; WF85-OF15: Wheat flour substituted with 15% oleaster; A-B: Within a column followed by the same letter are not significantly different ($P>0.05$).

3.3. Effect of the OF substitution on farinograph parameters

Farinograph tool is used to determine the kneading properties of dough and gives information about the bread features of WF. It has been considered as a sensitive tool for the study of modifications caused by fiber at the stage of development and mixing of bread doughs (Mis, Grundas, Dziki, & Laskowski, 2012). The resistance of dough against kneader pallets during kneading is shown on the farinogram. Therefore, information about the dough-forming properties of gluten is obtained.

In general, the flours with high stability and development time and low degree of softening have high technological value for bread-making. The length of the development time indicates the longer the kneading time, the high amount and quality of gluten. However, high degree of softening refers the inconvenience of dough for processing and low fermentation tolerance. In this study, the farinograms of WF with various concentrations of OF substitution (0, 5, 10 or 15%) was shown in Figure 1. Change in farinograph parameters, namely water absorption (%), dough development (min), stability (%) and degree of softening (BU) was also given in Table 3. Water absorption of the flour mixtures ranged from 51.85% to 57.25% while neat WF had the highest ($P<0.05$) water absorption value and increase of the OF content caused significant ($P<0.05$) decrease in absorption. In fact, fibers containing a number of hydroxyl groups have ability to interact water via hydrogen bonds, enabling them hydrophilic nature (Mudgil & Barak, 2013; Rosell, Rojas, & Benedito de Barber, 2001). However, the hydrophobic interaction occurred between dietary fibers of OF and wheat gluten, which resulted in decrease in water absorption of the flour, was likely due to the presence of soluble fibers which interacted with gluten non-covalently via hydrogen bonding and hydrophobic interactions (Zhou et al., 2021). Lower water absorption of the flour depending on the increasing OF concentration may also be due to the proportional decrease of wheat starch which possess strong hydrophilic nature.

As can be seen in Figure 3, all flour samples exhibited a rapid and abrupt start of dough development, which is mainly due to the formation of intense disulfide bonding in the gluten network (Huang et al., 2016). Intermolecular bonds between gluten molecules result in the binding of starch and other flour components (Mis, Nawrocka, & Dziki, 2017). In addition, it was clear that OF addition did not make any positive or negative effect on consistency of the WF, indicating its insignificant effect on gluten network formation, as also shown by dough development data in Table 3. As can be seen in Table 3, the OF substitution except for 10% did not significantly ($P>0.05$) influence the development time. It was shown that dough development stage is also affected from water absorption by the flour constituents, which supports our findings (Mis et al., 2017).

Stability (%) refers the difference in time between arrival and departure during the dough mixing. As seen in Table 3, the control sample had the highest ($P<0.05$) stability. 5% OF substitution of the WF did not make any significant ($P>0.05$) change in the stability while higher OF levels caused significant ($P<0.05$) reductions. The main reason of the decrease of stability is likely the dilution of gluten by the OF substitution higher than 5%, which was not tolerated by interaction of the dietary fibers with wheat gluten (Roberts, Cui, Chang, Ng, & Graham, 2012).

Degree of softening of the flour mixtures ranged from 62.00 to 122.50 BU (Table 3), which was mainly affected from the OF level. Increase in OF substitution caused significant ($P<0.05$) elevation in the degree of softening. This shows that rheological properties of the flour were negatively influenced from the OF addition and the dough structure was less stable against mixing. Similar results were also obtained by Mis et al. (2012) who reported that dough softening gradually increased from 63 to 12125 FU (farinograph unit) by the increase in the doses of oat wholemeal from 0% to 25%.

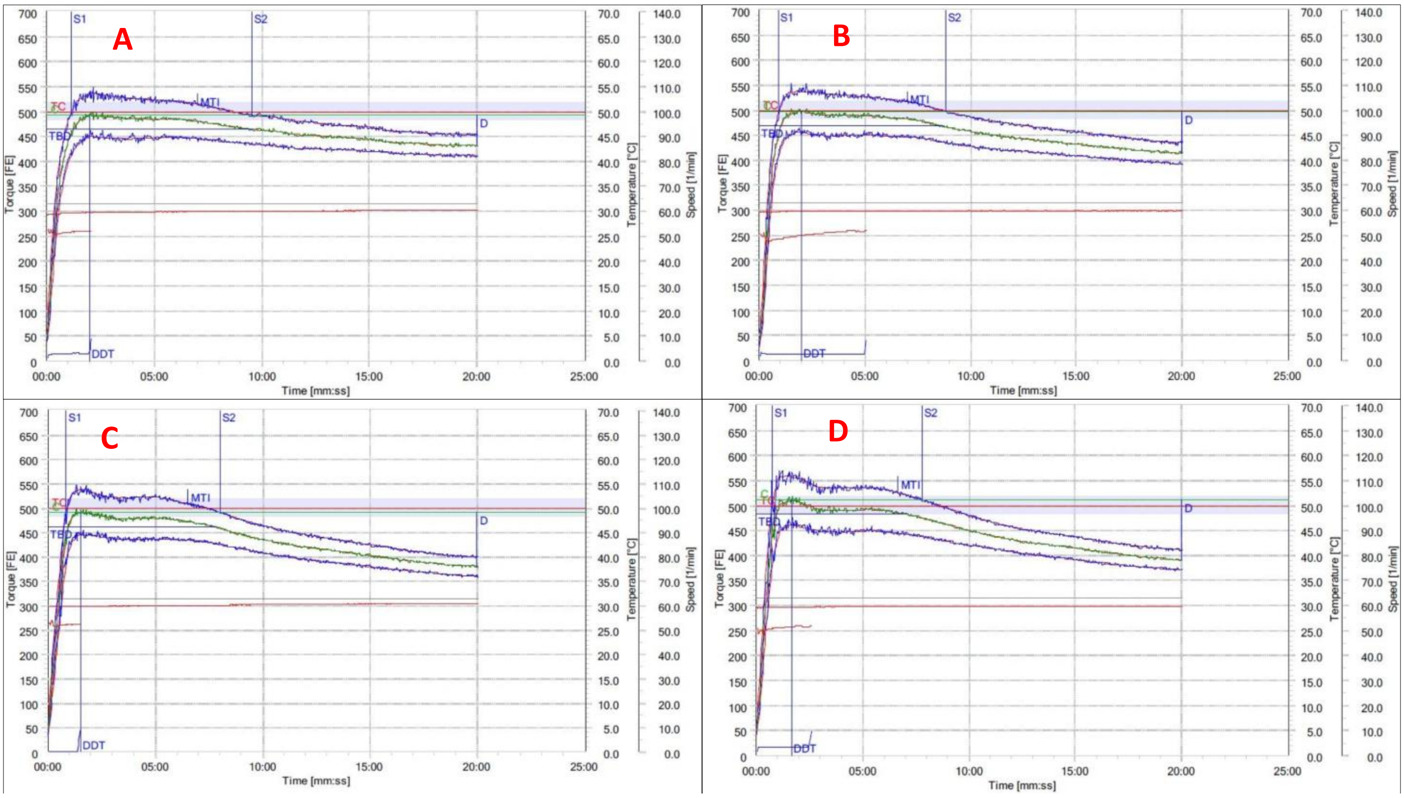

Figure 1. Farinograph curves of the wheat flour substituted with 0% (A), 5% (B), 10% (C) or 15% (D) of oleaster flour

Table 3. Farinograph properties of the flour mixtures.

Flour	Water absorption (%)	Dough development (min)	Stability (%)	Degree of softening (BU)
WF100	57.25±0.35^{A}	1.59±0.00^{A}	8.31±0.08^{A}	62.00±0.00^{C}
WF95-OF5	55.40±0.14^{B}	1.47±0.18^{BA}	7.32±0.34^{BA}	91.00±11.31^{B}
WF90-OF10	53.85±0.21^{C}	1.29±0.01^{B}	6.59±0.76^{B}	116.50±7.78^{BA}
WF85-OF15	51.85±0.21^{D}	1.37±0.04^{BA}	6.69±0.46^{B}	122.50±2.12^{A}

WF100: Wheat flour; WF95-OF5: Wheat flour substituted with 5% oleaster; WF90-OF10: Wheat flour substituted with 10% oleaster; WF85-OF15: Wheat flour substituted with 15% oleaster; A-D: Within a column followed by the same letter are not significantly different (P>0.05).

3.4. Effect of OF substitution on extensograph parameters

Variation on extensograph properties of WF as a result of OF substitution is presented in Table 4. Energy means the required energy for unit extension of the dough and gives information about the degree of processability of dough. Higher energy indicates the higher gas holding capacity and fermentation tolerance of dough (Bloksma, 1971). The volume of breads produced from high energy dough is also high. In general, addition of fibrous structures at higher degrees into dough damage the formation of the gluten network, which causes the dough to weaken (Ahmed et al., 2013; Ammar, Hegazy, & Bedeir, 2009; Koca & Anil, 2007). As seen in Table 4, the OF substitution significantly (P<0.05) increased gradually the energy of the dough at all proving time periods, indicating that the OF improved processing ability of the WF at all concentrations. Similarly, Mis et al. (2012) found that the addition of carob fiber caused an increase of energy, on average up to 129 cm^2. Anil (2007) also reported similar trends in energy values of the wheat dough incorporated with different levels of dry or hydrated hazelnut testa. This may be due to the variations in quality properties of wheat doughs, mainly affected by gluten proteins which form the skeletal network of dough (Hrušková, Švec, & Jirsa, 2006). Generally, increasing proving time to 90 min from 45 min did not cause a decrease in the energy while the energy decreased by the extending proving time to 135 min (Table 4).

As presented in Table 4, the extensibility of the WF substituted with the OF at different concentrations varied from 149.50 mm to 172.50 m, 147.50 mm to 184.50 mm and 164.00 mm to 182.00 mm at 45, 90 and 135 min of proving times, respectively. Although extensibility was affected from the OF addition, the decrease was insignificant (P>0.05) except for 90 min. In general, extending of proving time to 90 min did not increase extensibility, indicating the stability of the dough during longer periods. Our findings were in accordance with the results of Dimitrios Sabanis, Makri, and Doxastakis (2006) who reported that extensibility decreased with increasing the ratio of chickpea in the WF formulation. Mis et al. (2012) also found that with increase in the dose of carob fiber from 0% to 5%, the extensibility of the dough gradually decreased on average from 170 to 132 mm.

Resistance to extension refers the highest resistance of a dough during extension. Higher resistance to extension values represents that the dough has better processability and greater fermentation tolerance (Zhang et al., 2010). In this study, resistance to extension of the WF samples substituted with the

Table 4. Extensograph properties of the flour mixtures.

Parameter	Energy (cm^2)		
	45 min	**90 min**	**135 min**
WF100	71.50 ± 2.12^{B}	67.50 ± 2.12^{C}	56.50 ± 0.71^{C}
WF95-OF5	93.00 ± 4.24^{A}	87.00 ± 2.83^{B}	72.50 ± 2.12^{B}
WF90-OF10	98.00 ± 9.90^{A}	93.50 ± 7.78^{BA}	78.50 ± 4.95^{BA}
WF85-OF15	100.50 ± 9.19^{A}	105.00 ± 1.41^{A}	84.00 ± 1.41^{A}
Parameter	**Extensibility (mm)**		
	45 min	**90 min**	**135 min**
WF100	168.00 ± 9.90^{A}	184.50 ± 4.95^{A}	180.50 ± 3.54^{A}
WF95-OF5	172.50 ± 13.44^{A}	175.50 ± 3.54^{A}	182.00 ± 9.90^{A}
WF90-OF10	163.50 ± 9.19^{A}	160.00 ± 4.95^{B}	175.50 ± 0.71^{A}
WF85-OF15	149.50 ± 2.12^{A}	147.50 ± 0.71^{C}	164.00 ± 11.31^{A}
Parameter	**Resistance to extension (BU)**		
	45 min	**90 min**	**135 min**
WF100	250.00 ± 1.41^{C}	230.00 ± 7.07^{C}	204.50 ± 3.54^{C}
WF95-OF5	310.50 ± 6.36^{CB}	314.00 ± 26.87^{B}	260.00 ± 18.38^{B}
WF90-OF10	353.50 ± 30.41^{BA}	365.00 ± 31.11^{B}	280.00 ± 18.38^{B}
WF85-OF15	407.50 ± 41.72^{A}	449.50 ± 2.12^{A}	336.00 ± 7.07^{A}
Parameter	**Maximum resistance (BU)**		
	45 min	**90 min**	**135 min**
WF100	298.50 ± 7.78^{C}	268.00 ± 0.00^{C}	228.00 ± 0.00^{C}
WF95-OF5	370.50 ± 0.71^{CB}	366.50 ± 16.26^{B}	292.50 ± 17.68^{B}
WF90-OF10	431.00 ± 39.60^{BA}	421.50 ± 36.06^{B}	313.00 ± 19.80^{B}
WF85-OF15	462.50 ± 43.13^{A}	507.00 ± 11.31^{A}	359.50 ± 9.19^{A}

WF100: Wheat flour; WF95-OF5: Wheat flour substituted with 5% oleaster; WF90-OF10: Wheat flour substituted with 10% oleaster; WF85-OF15: Wheat flour substituted with 15% oleaster; A-D: Within a column followed by the same letter are not significantly different (P>0.05).

OF increased gradually (P<0.05) by the increasing OF concentration (Table 4). The increase of the proving time from 45 to 90 min caused an increase in the resistance to extension of the dough while further extending in the proving time from 90 to 135 min resulted in its reduction in the resistance. These results were supported by Mis et al. (2012) who tested extensograph parameters of wheat dough incorporated with oat wholemeal or carob fiber at different concentrations. Mohebbi, Homayouni, Azizi, and Hosseini (2018) also reported that incorporation of beta-glucan or resistant starch into dough provided higher resistance to extension values. Dimitrios Sabanis et al. (2006) also found similar findings in the case of addition of chickpea flour up to 20%.

Maximum resistance refers the maximum level of resistance measured during the constant extension of the dough and is used as an indicator of dough strength. As seen in Table 4, increasing OF substitution of WF gradually enabled higher (P<0.05) maximum resistance values at all proving times. A remarkable decrease in maximum resistance was obtained at 135 min of proving time as compared to 45 and 90 min. Similarly, Mohebbi et al. (2018) reported that the maximum resistance values of doughs with beta-glucan and resistant starch at all substitution levels were significantly higher than the control dough. Our results were also supported by different researchers (Li, Huang, Yang, & Wang, 2012; Dimitrios Sabanis et al., 2006). In contrast, Ahmed et al. (2013) reported lower maximum resistance levels by the enrichment of dough with water insoluble date fiber.

4. Conclusions

In this study, OF was used in the WF formulation as a dietary fiber source as well as other phytochemicals such as vitamins, minerals and phenolics. The OF substitution slightly decreased the sedimentation value of the WF. In the results of farinograph experiments, higher levels of OF caused decrease in water absorption, dough development and stability of the dough while softening value increased. Extensograph studies showed that the OF incorporation increased energy, resistance to extension and maximum resistance values of the wheat dough, indicating that better dough strength and processing properties were obtained with the presence of the OF. The extensogram results also showed that 90 min of proving time is required for an optimum gluten network formation for both control and the OF incorporated dough samples whereas extended proving caused structural relaxation of the gluten network. In conclusion, this study demonstrated that WFs substituted the OF at different concentrations in order to obtain a high dietary fiber formulation could be used for bread-making. However, effect of the OF on bread quality should be investigated.

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