

# Rye and oat flour enriched baked wheat chips: bioactive and textural properties

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## RESEARCH ARTICLE

### Abstract

This study investigates the effect of rye and oat flour incorporation into baked wheat chip formulation on the bioactive, textural and sensory attributes. The increase in the ratio of rye and oat flours ranging from 0-50% resulted in gradual increase in both total phenolic content and diphenylpicrylhydrazyl radical scavenging activity and the chip formulation of 50% wheat+50% oat had the highest values. Texture as assessed hardness value indicated that rye and oat flours addition leads to much more compact structure as compared to 100% wheat flour. Sensory analysis revealed that the samples containing rye and oat flour are acceptable as proved by their scores. It is therefore may be reasonable to fortify the wheat flour formulation with rye/oat flour to produce and health beneficial bakery product.

**Keywords:** baked wheat chip, rye and oat flour, enrichment, bioactivity, texture

### 1. Introduction

There has recently been great consumer demand for functional foods possessing higher level of bioactive ingredients such as anti-oxidants, fibre and minerals. Besides, busy lifestyles necessitate ready to eat meals and snacks with good nutritional value and therefore the food industry requires developing foods to meet the consumer expectations (Reis and Abu-Ghannam, 2014). Today consumers generally prefer nutritious and convenient snacks and 40% of them are looking for functional and 'on-the-go' handheld snacks (Sloan, 2011). Different types of snack foods are produced and consumed around the world. However, there is a tendency in food industry for the production of new generation of snacks containing low fat-high fibre and baked, snacks (Mazumder *et al.*, 2007).

There have been attempts to improve the nutritional value (Ajila *et al.*, 2008; Stojceska *et al.*, 2008; Sun-Waterhouse *et al.*, 2010) textural characteristics (Sanchez-Pardo *et al.*, 2010) of snacks foods. Different approaches such as the addition of fibre and protein flours into extruded and baked snacks (Ainsworth *et al.*, 2007) the use of nutritionally rich ingredients for bakery products, especially biscuits (Mildner-Szkudlarz *et al.*, 2015; Walker *et al.*, 2014) have

been employed. The importance of baked products has been increasing due to their easy consumption (Rosales-Soto *et al.*, 2012). New products incorporated with cereal (Prückler *et al.*, 2014), and functional fruit ingredients (Bajerska *et al.*, 2015) have been considered to increase in the near future due to presence of bioactive compounds.

Cereal grains contain various phenolic phytochemicals (Okarter and Liu, 2010). Among them, derivatives of benzoic and cinnamic acids as well as flavonoids, flavones and flavanols, anthocyanidins, avenanthramides, lignans and alkylresorcinols have been established and the phenolic acid content of cereals has generally been accepted as major contributor to antioxidant properties (Fardet, 2010; Peng *et al.*, 2015).

In recent years, oat based products have been gaining popularity due mainly to nutritional and therefore health advantages of oats (Aigster *et al.*, 2011; Rasane *et al.*, 2015). After the cholesterol-lowering effect of its soluble fibre component  $\beta$ -glucan, had been granted by Food and Drug Administration (FDA, 2005) and European Food Safety Authority (EFSA, 2009), oat-based breakfast cereals have been gained popularity for reducing cholesterol levels (AbuMweis *et al.*, 2010; Butt *et al.*, 2008) and the postprandial glycaemic

response (Thondre and Henry, 2009). The antioxidants and phenolic content of oats have also been emphasised (Peterson *et al.*, 2002). Oat flour has been reported to extend the shelf life of some cereal products for many years (Webster, 2002).

Rye is of the grain used in the bread formulations (Bushuk, 2001). Besides bread, rye has also been utilised in many other food products, such as breakfast cereals, etc. (Kujala, 2008) and comprises biologically active compounds possessing antioxidant properties (Lindhauer and Dreisoerner, 2003)

Baking process parameters such as the heating rate, humidity and time influence the final product quality (Berk, 2009; Hadiyanto *et al.*, 2007). The heat and mass transfer occurring during bread baking cause physical, chemical and structural transformation and temperature is considered as the critical parameter influencing various physicochemical changes (Le Bail *et al.*, 2009).

In this study, it is aimed at examining the suitability of oat and rye flours for nutritionally improved (source of antioxidants) wheat based and baked chip formulation. Production of an innovative baked snack that will provide the ways of alternative uses of wheat and meeting the consumer demands for the products possessing health improving and acceptable sensory properties was also targeted.

## 2. Materials and methods

### Materials

The wheat flour was acquired from Hilal Değirmencilik A.Ş. (Nevşehir, Turkey). The technological parameters of the wheat flour sample were reported by the company as moisture: 14.0%, wet gluten: 24.8%, gluten index: 98%, zeleny sedimentation value: 31 ml, falling number value: 376. Rye and oat flours were obtained from Ataer Food Co., (Istanbul, Turkey).

### Preparation of chips

The formulations containing different levels of wheat, whole meal, oat and rye flours used in chip preparation were presented in Table 1. The dry mixture of flours were first homogenised for 2 min kneaded with water (100:60 w/w) using a food processor (Kitchen Aid Classic, Michigan, MI, USA) for 90 sec at low speed (level 2) and then 90 sec at high speed (level 4). The dough was wrapped with stretch film and rested 30 min at room temperature. The dough was gradually (16, 8, 4, 2 and finally to 1 mm) rolled out (Rondo Doge, SS0615, Burgdorf, Switzerland) and the dough was stamped out in rectangular shape having 3 cm and 6 cm side lengths. After making 32 point pin holes on the top of shaped dough slices, baking were carried out in the oven (Unox srl, Cadoneghe, Italy) adjusted to 210 °C

**Table 1. Chips formulations.**

Sample	Formulation
1	100% wheat
2	100% whole meal
3	90% wheat+10% rye
4	80% wheat+20% rye
5	70% wheat+30% rye
6	60% wheat+40% rye
7	50% wheat+50% rye
8	90%wheat+10% oat
9	80%wheat+20% oat
10	70%wheat+30% oat
11	60%wheat+40% oat
12	50%wheat+50% oat

for 4 min. After cooling to room temperature, chip samples were transferred into mini ziplock bags.

### Extraction

Chip samples (1 g) were powdered extracted with methanol (10 ml, 80% v/v) for 2 h at 37 °C, centrifuged (Nüve, NF 800R, Ankara, Turkey) at 12,000×g for 15 min and then filtered (Anton *et al.*, 2009).

### Total phenolic content

Two hundreds µl of the extract was mixed Folin-Ciocalteu reagent (1.5 ml) of previously diluted 10 times with distilled water and rested for 5 min. After adding sodium bicarbonate solution (1.5 ml, 6% w/v), the mixture was incubated for 90 min at room temperature then the absorbance value was determined at 725 nm (UV – 1700 Pharmaspec, Shimadzu, Kyoto, Japan). The results were expressed as mg gallic acid equivalent (GAE)/g d.m. sample.

### DPPH radical scavenging activity

Chip extract (200 µl) was mixed with diphenylpicrylhydrazyl (DPPH) solution (500 µl) and 80% methanol (4 ml). The mixture was incubated for 30 min in dark at room temperature and then the absorbance was measured (UV – 1700 Pharmaspec, Shimadzu) at 517 nm. DPPH radical scavenging activity was calculated by using the equation: inhibition (%) = (Absorbance blank – Absorbance sample) × 100 / Absorbance blank (Anton *et al.*, 2009).

### Texture analysis

The textural analysis was carried out a Texture Analyzer (TA. XT Plus, Stable Micro System Ltd., Surrey, England) using a Kramer shear cell (HDP/KS-5, 30 kg). Three pieces of wheat

chips were situated in the Kramer shear cell and test was performed at the speed of 5 cm/min. The maximum force required to break the sample as the fracture force (hardness, N) was calculated from the time-deformation curve.

### Sensory analysis

For the sensory analysis of the samples, a panel consisting of 12 members, including postgraduates of Dept. of Food Engineering, Erciyes University (Kayseri, Turkey) was established. Panelists evaluated the colour, flavour, crispness and overall acceptability of the representative chip samples (100% wheat, 100% whole-wheat, 50% wheat+50% rye and 50% wheat+50% oat) and sorted the chip samples using a 4-point rating scale ranging from like extremely (4) to dislike extremely (1). The panellists were trained to become familiar in sensory evaluation. Samples were assigned random codes and the analysis was performed three times.

### Statistical analysis

The experimental data were analysed statistically using ANOVA and significant differences at  $P < 0.05$  were evaluated by Tukey multiple comparison test.

## 3. Results and discussion

### Total phenolic contents

The values were displayed in the Table 2. The result showed that rye and flour incorporation into wheat flour had significant ( $P < 0.05$ ) effect on total phenolic content of different formulations.

**Table 2. Total phenolic content (mg GAE/g d.m) values (average  $\pm$  standard deviation) of chips samples.<sup>1</sup>**

Formulation	Total phenolic content <sup>2</sup>
100% wheat	112.41 $\pm$ 2.83 <sup>j</sup>
100% whole meal	234.06 $\pm$ 0.94 <sup>c</sup>
90% wheat+10% rye	158.47 $\pm$ 3.30 <sup>i</sup>
80% wheat+20% rye	196.32 $\pm$ 1.13 <sup>ef</sup>
70% wheat+30% rye	201.17 $\pm$ 1.36 <sup>e</sup>
60% wheat+40% rye	210.35 $\pm$ 1.61 <sup>d</sup>
50% wheat+50% rye	235.26 $\pm$ 1.72 <sup>c</sup>
90%wheat+10% oat	173.67 $\pm$ 1.42 <sup>h</sup>
80%wheat+20% oat	190.11 $\pm$ 2.85 <sup>fg</sup>
70%wheat+30% oat	235.02 $\pm$ 1.41 <sup>c</sup>
60%wheat+40% oat	244.75 $\pm$ 1.75 <sup>b</sup>
50%wheat+50% oat	311.89 $\pm$ 4.59 <sup>a</sup>

<sup>1</sup> GAE = gallic acid equivalent.

<sup>2</sup> a-j: different letters in the same column indicate statistically significant ( $P < 0.05$ ) differences.

The highest total phenolic content (311.89) was obtained from the 50% wheat+50% oat formulation, whereas wheat flour had the lowest value (112.41). The incorporation of rye and oat flours from 10 to 50% led to steady increase in total phenolic content. The alterations of the phenolic content during baking may result from some factors such as baking temperature and chemical nature of phenolic compounds (Rumiyati *et al.*, 2015). The phenolic compounds are extracted using various methods and solvents may result in differences in the values therefore comparison of the data is irrelevant. However, heat treatment (baking) has been reported to increase the total phenolic content to certain degree (Gelinas and McKinnon, 2006) or decrease (Leenhardt *et al.*, 2006). For example, baking of muffin incorporated with apple skin powder has been reported to result in a decrease phenolic content (Rupasinghe *et al.*, 2008). Phenolics are highly reactive compounds (Cheynier, 2005) and the method of estimation (Stratil *et al.*, 2007), heat-induced Maillard reaction products (reductones and melanoidins) (Samaras *et al.*, 2005) and polymerisation and oxidation (Randhir *et al.*, 2008) might be a contributing factors for the variation in the reported results.

### DPPH radical scavenging activity

Free radical scavenging ability of the samples is generally estimated by DPPH (Shimoji *et al.*, 2002). DPPH radical scavenging activity values (% inhibition) were given in Table 3.

The dough samples of wheat flour that were baked at 210 °C for 4 min had an inhibition (%) value of 17.37 while the value for whole meal sample was 42.4. A gradual increase was observed by the increase in the percentages of the addition of

**Table 3. DPPH radical scavenging activity (% inhibition) values (average  $\pm$  standard deviation) of chips samples.**

Formulation	DPPH <sup>1</sup>
100% wheat	17.37 $\pm$ 0.58 <sup>f</sup>
100% whole meal	42.40 $\pm$ 0.18 <sup>a</sup>
90% wheat+10% rye	24.19 $\pm$ 0.13 <sup>e</sup>
80% wheat+20% rye	25.27 $\pm$ 1.54 <sup>e</sup>
70% wheat+30% rye	31.66 $\pm$ 0.37 <sup>d</sup>
60% wheat+40% rye	32.50 $\pm$ 0.94 <sup>d</sup>
50% wheat+50% rye	35.84 $\pm$ 0.49 <sup>c</sup>
90%wheat+10% oat	30.12 $\pm$ 1.02 <sup>b</sup>
80%wheat+20% oat	33.08 $\pm$ 2.18 <sup>dc</sup>
70%wheat+30% oat	35.21 $\pm$ 0.99 <sup>c</sup>
60%wheat+40% oat	38.99 $\pm$ 0.60 <sup>b</sup>
50%wheat+50% oat	42.03 $\pm$ 0.95 <sup>a</sup>

<sup>1</sup> a-j: different letters in the same column indicate statistically significant ( $P < 0.05$ ) differences; DPPH = diphenylpicrylhydrazyl.

rye and oat flours. The increase was much more pronounced for the oat supplemented samples which lead to a value of 42.3% inhibition in the case of 50% addition. The increase in DPPH radical scavenging activity in baked products as a result of the incorporation of mango peel powder has been reported (Ajila *et al.*, 2008). The existence of phenolics in cereal flours may promote the antioxidant activity (De la Parra *et al.*, 2007; López-Martínez *et al.*, 2009). Ferulic acid of wheat flour (Beta *et al.*, 2005) and baking induced Maillard reaction products (González-Mateo *et al.*, 2009) has generally been considered as contributing factors to the antioxidant activity of the baked samples.

### Physical properties

The hardness values of chip samples were displayed in the Table 4. The texture, taste and appearance are important parameters affecting the acceptability of the snacks (Dehghan-Shoar *et al.*, 2010).

Texture is a key complex parameter sensed by a combination of sensory faculty and employed for quality evaluation of food products (Szczeniak, 2002). The maximum force required to form a certain deformation generally defined as hardness (Bandopadhyay *et al.*, 2005). While the texture as indicated by hardness value of control sample (100% wheat flour) was 310.35 N, whole meal chip samples had a statistically significant ( $P < 0.05$ ) higher hardness value of 340.83 N. The addition of rye and oat flours to the wheat flour identically resulted in the increase in the hardness value (Table 4). The textural properties of tortilla chips during the baking process has been related to the quick transfer of moisture at high temperatures leading to the formation of larger air cells and cracks in the structure

**Table 4. Hardness (N) values (average±standard deviation) of chips samples.**

Formulation	Hardness (N)
100% wheat	265.72±4.84 <sup>d</sup>
100% whole meal	343.58±12.04 <sup>a</sup>
90% wheat+10% rye	280.91±45.25 <sup>bcd</sup>
80% wheat+20% rye	283.05±29.21 <sup>bcd</sup>
70% wheat+30% rye	298.78±7.38 <sup>bc</sup>
60% wheat+40% rye	304.86±13.85 <sup>bc</sup>
50% wheat+50% rye	310.55±9.72 <sup>b</sup>
90%wheat+10% oat	277.72±8.27 <sup>cd</sup>
80%wheat+20% oat	283.17±24.36 <sup>bcd</sup>
70%wheat+30% oat	298.35±5.45 <sup>bc</sup>
60%wheat+40% oat	304.48±3.68 <sup>bc</sup>
50%wheat+50% oat	311.23±13.96 <sup>b</sup>

<sup>1</sup> a-j: different letters in the same column indicate statistically significant ( $P < 0.05$ ) differences.

(Kayacier and Singh, 2003, Sánchez-Madrigal *et al.*, 2014). In a study which focused on the effect of the addition of sorghum and rice flour into the formulation found that the tortilla chips were more crispy and brittle (Quintero-Fuentes *et al.*, 1999).

### Sensory analysis

The consumption of cereal foods in all food cultures mainly depend on the consumer acceptability determined by sensory quality and the availability of products (Poutanen *et al.*, 2014). The sorting test results of the samples that were obtained from four different flour formulations were displayed in Table 5. It was determined that there was a difference in the grades given for the samples.

The samples that were obtained from 100% wheat flour samples were ranked first and 50% rye+50% wheat flour samples second. The 100% whole meal flour chips was the least liked and least preferred compared to other chip samples. It has been known that the bran content of whole meal flour negatively affect the quality of cereal products (Noort *et al.*, 2010). Especially flavour of whole grain products is generally associated with negative sensory attributes (Bin *et al.*, 2012). It was also reported that a few people preferred the taste of whole grains and therefore the biggest barrier to whole grain consumption (McMackin *et al.*, 2012).

## 4. Conclusions

The present study indicated that formulations combining the wheat flour, rye and oat flours at various percentages generally resulted in higher total phenolic content and the antioxidant activity. In addition the textural attribute as measured hardness value and sensory acceptability scores

**Table 5. Sensory evaluation of representative chip samples.**

Panellists	50% oat + 50% wheat	50% rye + 50% wheat	100% wholemeal	100% wheat
1	2	3	1	4
2	3	2	1	4
3	3	2	1	4
4	2	4	1	3
5	3	4	2	1
6	4	2	1	3
7	2	3	1	4
8	1	4	2	3
9	2	4	1	3
10	1	4	2	3
11	2	3	1	4
12	3	2	1	4
Total	28	37	15	40

of rye and oat flour supplemented samples, except 100% wheat, were better than other samples. Therefore it is logical to include rye and oat flour into bakery formulations as a beneficial ingredient which possibly may lead to a product having better health improving properties.

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