

ORIGINAL RESEARCH PAPER

EFFECT OF POTATO (*Solanum tuberosum*) ADDITION ON THE DOUGH PROPERTIES, SENSORY QUALITIES AND RESISTANT STARCH CONTENT OF BREAD

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The aim of this study is to assess the effects of adding different varieties of boiled potatoes-pasta (PP), Impala (I) and Orchestra (O), to wheat flour in bread making. These potato varieties were used to replace wholemeal 1250 type flour (F₁) and hard wheat semolina flour (F₂) in different concentrations: 5%, 10%, 20%, 30%. The rheological properties of dough with added potato were assessed by means of the flour-graphic technique. The study also determined the amount of resistant starch (RS), non-resistant starch (n-RS), total starch (TS) and moisture content of the potato bread. The results showed that the water absorption (WA) in the potato dough containing salt and yeast decreased by 28.8% (F₂-I-PP), and by 41.2% (F₁-I-PP) respectively. The same happened with the dough development time, dough stability and quality number. We found out that the degree of dough softening was increased, as was the moisture content of the bread, which went from 47.7% (O-PP-F₂) to 50.3% (I-PP-F₁). The level of the ten analyzed sensory properties led to the conclusion that, by adding up to 20% PP, we enhance the bread quality. The RS content increased by 5.1 g/100 g d.m. for F₁ bread for the 30% (O-PP-F₂) potato content batch. In F₂ bread, the RS content increased by up to 5.11g/100 g d.m. for the 30% (O-PP-F₂) potato content batch. Given the method of analysis, RS may be a mixture of RS₂ (natural granule starch) and RS₃ (retrograde or non crystalline retrograde). Therefore, potato bread is very healthy and recommended for its nutritional benefits.

Keywords: dough rheology, potato bread, sensory evaluation, in vitro digestion, resistant starch

Introduction

Potatoes are one of the most important staple crops for human consumption, together with wheat, rice and corn (FAO 2008). The potato is dietary and a source of energy due to its carbohydrate level. In October 2007, the United Nations declared 2008 as “*The Year of the Potato*”, highlighting the importance of this crop as a staple food in human nutrition (Schieber *et al.*, 2009). The potato and the sweet potato (*Ipomoea batatas*) are an important crop in many parts of the world (Woolfe, 1992).

The flour quality can be defined as a set of parameters that assure the possibility to obtain certain final bakery products of a desired quality. This set of parameters includes technological and rheological wheat flour parameters that define dough behaviour during the mixing processes. In the bread making industry many instruments have been developed for testing the rheological properties of the dough, the most commonly used are those during mixing (e.g. farinograph and flourgraph) (Hwang, *et al.*, 2001; Jbeily, *et al.*, 2014). Bread is a traditional food consumed throughout the entire world. Two raw materials rich in starch are used in making potato bread. There is a change in starch value fractions during the bread making processes. For determining these fractions, we used an enzymatic "in vitro" method of digestion outside the body employing exogenous digestive enzymes. Resistant starch (RS) is considered to be potentially prebiotic and provides health colonocytes (Bird *et al.*, 2000; Topping, *et al.*, 2003).

The potential health benefits of slowly digestible starch are related to glucose metabolism, diabetes, mental performance and satiety (Lehman *et al.*, 2007). It also contributes to the prevention of diseases caused by syndromes such as insulin-resistant diabetes, atherosclerosis, and obesity.

Bread, accounting for approximately 27% of the total resistant starch intake by the Mexican Americans, was the main source of resistant starch for this population. All types of bread, cooked cereals/pastas, and vegetables (other than legumes) contributed as 21%, 19%, and 19% of the total resistant starch intake (Murphy, *et al.*, 2008). RS is part of several categories that are differentiated by the degree of starch digestibility. RS₁ is physically strong, RS₂ is the granular structure, RS₃ is retrograde or non crystalline retrograde starch, RS₄ is the chemically modified or repolymerized starch, RS₅ designates complexes with lipids (Sharma, *et al.*, 2008; Fuentes-Zaragoza, *et al.*, 2011). Accordingly, gelatinizing the starch and subsequently storing it leads to the rapid decrease of starch digestion, and the increase of the resistant (Chung, *et al.*, 2009). The method of determining the in vitro digestion used is one that has evolved over time. A procedure was developed based on the thermal treatment (Berry, 1986). Then it turned to digestion with α -amylase and pullulanase (Englyst and Cumming, 1985, 1987). There are correlations with other methods for determining the RS (Akberg, *et al.*, 1998). Researchers have developed a procedure in which the sample was chewed in the mouth, and then was treated with pepsin and pancreatic acid mixed with α -amylase and amyloglucosidase (Muir and O'Dea, 1992). More recent methods are developed (Faisant, *et al.*, 1995; Goni, *et al.*, 1996; Champ, *et al.*, 1999; 2000, McCleary, *et al.*, 2002). These include changes in the enzyme concentration, the type of enzyme used. All these changes have had an impact on determining the level of RS. While some problems have been solved, like the effects of the concentration of the pancreatic α -amylase, the pH of the incubation, the importance of the inhibition of maltose on the action α -amylase or vice versa, including the amyloglucosidase, we still need to determine the effect of stirring and mixing and to solve the problems of reconstructing and analyzing the resistant starch content of the samples.

The objective of this study was to assess the effects of replacing part of the wheat flour with different varieties of potatoes in bread making. We replaced type 1250 whole wheat flour (F_1) and hard wheat semolina flour (F_2) with potato in different concentrations: 5%, 10%, 20%, 30%. The rheological properties of the potato dough will be assessed as part of the study. The sensory analysis of the potato bread and the macroscopic assessment of the organoleptic properties are also relevant. The RS content and the moisture content of the potato bread will also be determined as part of the study. The predictive results of the quality of the potato bread will be determined by using the flour-graphic technique, the physical treatment and their influence in changing proportions of starch fractions in bread.

Materials and methods

Raw material and methods of analysis.

Used the wheat brown flour type 1250 (Mill Cibin Sibiu, Romania), had the following characteristics: wet Gluten (%) (ICC Standard No. 106/1(1984)) (29.8%); deformation index (mm) (SR 90:2007) (8 mm); glutenic index (SR 90:2007) (47.4); moisture (%) (ICC Standard No. 110/1 (1976)) (13.9 %); Falling Number(s) (ICC Standard No. 107/1, 1995) (290-300s); titratable acidity (degree) (SR 90: 2007) (4 degree); ashes (%) (ICC Standard No. 104/1, (1990)) (1.250%); water absorption (WA) (%) (ICC-Standard 115/1, 1998) (60.5%); resistant starch 1.1g/100g d.m.; total starch 76% (AOAC Method 2002.02); the semolina flour from durum wheat (Mill Cibin, Romania) had the following characteristics: humidity 13.6%; wet gluten 32%; gluten deformation 3.2 mm; gluten index 58; Falling Number 350s; titratable acidity 2.1 degree; WA from flour 53%, resistant starch 3.1g/100g d.m., total starch 78.8% the white potato, *Orchestra* variety (Potato Research and Development Station Târgu Secuiesc, Covasna, Romania) with moisture PP, 81.3%, resistant starch 1.2 g/100 g d.m., total starch 16%. The same method was used as with the brown flour wheat. We used yellow potatoes of the *Impala* variety which is characterized by lower starch content, pasta moisture of 83.5%, resistant starch 2.3 g/100g d.m., total starch 14%, the salt (Salina Ocna Mureş-Alba, Romania), bakery yeast (Pakmaya-S.C. Rompak S.R.L, Paşcani, Romania), with growth power of 10 min.

Preparing the potato pasta (PP)

Potato pasta (PP) was obtained by hydro thermal processing of the unpeeled raw potato for 30 minutes at water boiling temperature, then by cooling it, peeling, and mashing it by passing it through the 2 mm mesh sieve (Iancu, et al., 2010).

Dough rheological characteristics

Flourgraph characteristics were determined according to the ICC method. The parameter determined by means of Flourgraph E6 was water absorption-percentage known as water required to yield dough consistency of 500 HE (Haubelt Einheit) (Haubelt model, Berlin Germany). The ICC procedure no.179 (2012) was used.

Flourgraph test

Water absorption, arrival time, mixing time, stability and softening of wheat flour dough and its blends with potato pasta salt and yeast were determined according to ICC procedure methods, using a Flourgraph E6. A quantity of 100 grams of tested samples (14% moisture basis) was used (Iancu, *et al.*, 2010).

Bread making process

The baking test was carried out in an electric oven with an incorporated proofing chamber (type ESM 3710 SADKIEWICZ, Poland). The yeast was preliminary suspended in warm water (35°C) and was afterwards mixed with the flour and potato pasta, for 12 min, by means of a laboratory mixer (JZ SADKIEWICZ-Poland). The dough was proofed at 30 °C for 120 min and afterwards baked at 230 °C for 25 minute, following steaming for 15s. Measurements of the loaves were carried out after cooling to room temperature for 2.5 h (Iancu, *et al.*, 2011).

Sensory analysis of bread

The following elements are assessed by sensory analysis: bread appearance, symmetry of shape, size, colour and crust structure, crumb elasticity and porosity, taste, smell, signs of microbial modification and the presence of foreign bodies. It is basically an organoleptic examination that is a form of assessment by means of the senses. A Romanian scoring scheme was used and each of the properties analyzed was given a number of points. The maximum number of points was 20, minus a maximum of 0.5-1 points of penalty for each characteristic (Bordei, 2007). A team of 20 members, girls and boys aged 19 to 22, students of the *Faculty of Food Industry*, was asked to perform the sensory evaluation of the potato bread.

Bread chemicals component

Humidity bread was determined by using the classical "oven" method. The model we used was ESAC-50 Electronic April-Romania.

Measurement of RS, n-RS, TS in bread with potato, potato and flour

Samples are incubated in a shaking water bath with pancreatic α -amylase and Amyloglucosidase for 16 hour at 37°C. We used the heating bath (Memmert-Germany), during which the time non-resistant starch is solubilized and hydrolyzed to glucose by the combined action of the two enzymes. The reaction is terminated by the addition of an equal volume of ethanol or industrial methylated spirits and RS is recovered as a peeled on centrifugation. The used centrifuges were NF-800R Nüve-Turkey. This is then washed twice by suspension in aqueous IMS or ethanol IMS or ethanol (50% v/v), followed by centrifugation. The free liquid is recovered by decantation. RS in the peeled is dissolved in 2 M KOH by vigorously stirring in an ice/water bath oven a magnetic stirrer. This solution is neutralized with acetate buffer and the starch is quantitatively hydrolysed to glucose with AMG. Glucose is measured with glucose oxidase/peroxidase reagent (GOPOD), and this is a measure of the RS content of the sample. Non-RS (solubilized starch) can be determined by pooling the original supernatant and the washing, adjusting the volume to 100 ml and measuring glucose content with GOPOD. We used a T80 UV-VIS spectrophotometer (PG Instrument Ltd-England). The assay kit was purchased from

Megazyme International Bray Business park, Bray, Co Wicklow, Ireland – based on the AOAC Method 2002.02.

Statistical analysis

For calculating the fractions of starch based on the practical results, we used Mega-CalculTM (Megazyme, Ireland). The statistical analysis of the results was performed by means of Excel Program, Microsoft Office 2007.

Results and discussion

The purpose of the present study was to determine the influence of the different varieties of potato pulp on the rheological properties of dough, on the sensory properties of bread and the variation in its starch content. The flour-graphic technique was used to decide on the best recipe for potato bread (Iancu, *et al.*, 2010). Potato pulp, salt, and compressed yeast were found to contribute to the amount of water needed for dough kneading. If the required amount of water that would ensure the 500 HE dough consistency is not added, then the added salt (S) and yeast (Y) will decrease dough consistency for the same amount of water added. This effect is increased by adding potato pulp (PP) (Table 1).

After adding water in the presence of salt and yeast, we observed that the dough consistency decreased in the control sample by up to 11.1% in F₁ and by up to 1.4 in F₂. Table 1 shows that the decrease in dough consistency is proportional to the increase in the proportion of potato paste that replaces flour. Salt and yeast addition brings about a smaller decrease in dough consistency

There was an obvious decrease in WA in all the examined samples (Figure 1). It was observed that salt and yeast decrease the hydration capacity in the F₁ flour sample from 60.5% to 58.7% and have no effect on F₂ flour sample (53%). The addition of potato pulp decreases the WA while increasing the percentage of potato pulp replacing the flour content. There was a significant difference between the batch with 5% potato supplement and the one with 30% potato supplement. The most significant decrease was found in the F₂ flour sample. Although very small changes were initially seen in the dough made from this type of flour, with the increase in the amount of PP, WA was significantly reduced, from 53% to 28.8%. This is because the PP added is already hydrated and crushed. If up to 3% potato pulp is added to the dough, WA increases. Addition of other materials such as orange peel brings about an increase in WA, directly proportional with the amount of orange peel supplement (Kucerova *et al.*, 2013). This means that the moisture of the supplement influences the WA level (Raj and Masih, 2014).

Table 1. Effects of the potato pasta, salt and yeast additions on loss of consistency flourgraphic

Dough type ^a	Loss of consistency [HE]							
	F ^b ₁				F ^c ₂			
	O-PP ^d	O-PP-S-Y ^e	I-PP ^f	I-PP-S-Y ^g	O-PP ^h	O-PP-S-Y ⁱ	I-PP ^j	I-PP-S-Y ^k
Control	501	445	501	445	500	493	500	493
5%	401	459	447	463	417	463	410	481
10%	341	461	335	479	347	456	336	487
20%	257	425	327	425	251	451	259	468
30 %	198	419	269	420	196	440	171	460

^a -variant of work (control, flour was replaced with potato pulp at a rate of 5%, 10%, 20%, 30%.); ^b - the wheat brown flour type 1250; ^c - the semolina flour from durum wheat; ^d - F₁ replaced with potato pulp *Orchestra* variety; ^e - F₁ replaced with potato pulp *Orchestra* variety, salt and yeast; ^f F₁ replaced with potato pulp *Impala* variety; ^g - F₁ replaced with potato pulp *Impala* variety salt and yeast; ^h - F₂ replaced with potato pulp *Orchestra* variety; ⁱ - F₂ replaced with potato pulp *Orchestra* variety, salt and yeast; ^j - F₂ replaced with potato pulp *Impala* variety; ^k - F₂ replaced with potato pulp *Impala* variety salt and yeast

Other values of the measured variables, such as the development and stability time, presented in Table 2, show that the addition of PP generally decreases dough formation and stability time. The arrival time is reduced by up to 72.5% in dough made from F₁ flour and by up to 56% in dough made from F₂ flour. We can conclude that the values are different and influenced by the type of flour and variety of potato used.

Quality Number (QN) also decreases with the increase in the amount of potato pulp replacing the flour content (Figure 2). We observed that the F₂ dough presented lower values than the F₁ dough. Yeast and salt improved the QN value in F₁ flour. When adding PP, the QN value decreases by up to 88.3%. On the contrary, when F₁ flour and *Impala* potato were used, the values decreased by only up to 16%. Almeida *et al.*, 2010, argue that adding fibers to dough reduces dough stability. This conclusion is confirmed by the present study, even if the supplements used here are hydrated, moist and contain other elements, such as: soluble non-digestible fibers, pre-gelatinized starch, minerals, and so on. Each batch showed different results, influenced by the type of flour used, by the amount of PP used to replace the flour and by the variety of potato used. It was observed that, by diluting the gluten content, the values of the parameters measured were similar to the specific values of poor quality flour.

Therefore, the potential of the other macromolecular component that contributes to bread formation, namely starch, will be analyzed in what follows. Previous studies were used to create recipes suitable for each batch. Although flour-graphic studies did not predict positive results, this is what actually happened. As figure 3 shows, bread with 5 to 10% addition of potato pulp looks better than the control sample. There is an increase in loaf specific volume and an improvement in crust colour. Bread crumb moisture is also very important.

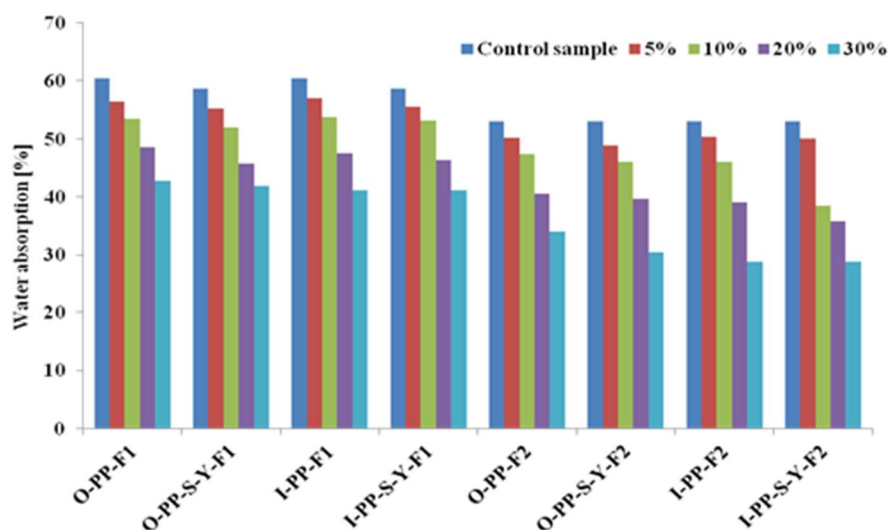


Figure 1. The effect of potato pasta, salt and yeast on water absorption:

O-PP-F₁ replaced with potato pulp Orchestra variety; O-PP-S-Y-F₁ replaced with potato pulp Orchestra variety, salt and yeast, I-PP-F₁ replaced with potato pulp Impala variety; I-PP-S-Y-F₁ replaced with potato pulp Impala variety salt and yeast; O-PP-F₂ replaced with potato pulp Orchestra variety; O-PP-S-Y-F₂ replaced with potato pulp Orchestra variety, salt and yeast; I-PP-F₂ replaced with potato pulp Impala variety; I-PP-S-Y-F₂ replaced with potato pulp Impala variety salt and yeast.

Sensory analysis

The screening test for the sensory evaluation of bread with a 5-30% PP supplement is shown in figure 4. The crumb of the F₁ control sample was slightly brittle, while the crust was shiny and of an even light brown colour. The test score of bread sample I-PP-F₁ was the highest, 19 points, in the 10% potato supplement batch. The crumb of the control sample was not crumbly, and the crust was shiny and of an even light brown colour. As it can be seen in the photos in Figure 3, the colour of the crust of the bread made with Impala potato is reddish-brown and uneven. The crust is blistered in the 20% and 30% potato supplement batches. The bread crumb exhibits uniform porosity, the pore walls are thinner; the crumb is well-aerated and darker, almost grayish in colour. There are no traces of potato pulp in the bread crumb, even in the 30% potato supplement batch. The higher the potato content, the more enhanced the flavor and the taste, also due to the particular cooking properties of the potato variety used. Its slicing properties have also improved. The test score of bread O-PP-F₂ is the highest, with a maximum of 18.5 points, in the batch with 20% potato content (figure 4). As it can be seen in the photographs, the crust colour of the bread made with Orchestra potato is reddish-brown rather than light brown. The bread properties are improved in the batches with up to 20% potato pulp added. The score of bread I-PP-F₂ is the highest: 18.5 points in the batch with 20% potato content. The analyzed organoleptic properties are the same in all batches.

Table 2. Flourgram parameters for dough prepared from wheat flour and potato pasta, salt(S) and yeast(Y)

Dough type ^a	Dough development time [min]				Dough stability [min]			
	O-PP ^e	O-PP-S-Y ^f	I-PP ^g	I-PP-S-Y ^h	O-PP ^e	O-PP-S-Y ^f	I-PP ^g	I-PP-S-Y ^h
F^b₁								
Control	4	6.6	4	6.6	4.1	9	4.1	9
5%	5.6	5.5	4.5	6.6	8.2	9.7	6.5	9.2
10%	1.6	1.6	1.7	1.3	5.3	7.8	4.3	1.5
20%	1.3	1.3	1.4	1.2	1.4	1.4	1.4	1.4
30%	1.1	1.1	1.2	1.3	1.1	1.4	1.4	1.4
F^c₂								
Control	3.8	5	3.8	5	3.6	6.6	3.6	6.6
5%	4.1	5.4	4.3	4.6	4.1	6.9	3.8	6.4
10%	4.1	5.4	3.8	4.4	3.9	6.4	3.8	5.6
20%	4	4.3	4	4.9	4.1	5.3	4.3	5.7
30%	1.9	2.2	3.6	3.4	3.7	4.6	4.3	5.2

^a -variant of work (control, flour was replaced with potato pulp at a rate of 5%, 10%, 20%, 30%.); ^b - the wheat brown flour type 1250; ^c - the semolina flour from durum wheat; ^d - F₁ replaced with potato pulp *Orchestra* variety; ^e - F₁ replaced with potato pulp *Orchestra* variety, salt and yeast; ^f F₁ replaced with potato pulp *Impala* variety; ^g - F₁ replaced with potato pulp *Impala* variety salt and yeast; ^h - F₂ replaced with potato pulp *Orchestra* variety; ⁱ - F₂ replaced with potato pulp *Orchestra* variety, salt and yeast; ^j - F₂ replaced with potato pulp *Impala* variety; ^k - F₂ replaced with potato pulp *Impala* variety salt and yeast

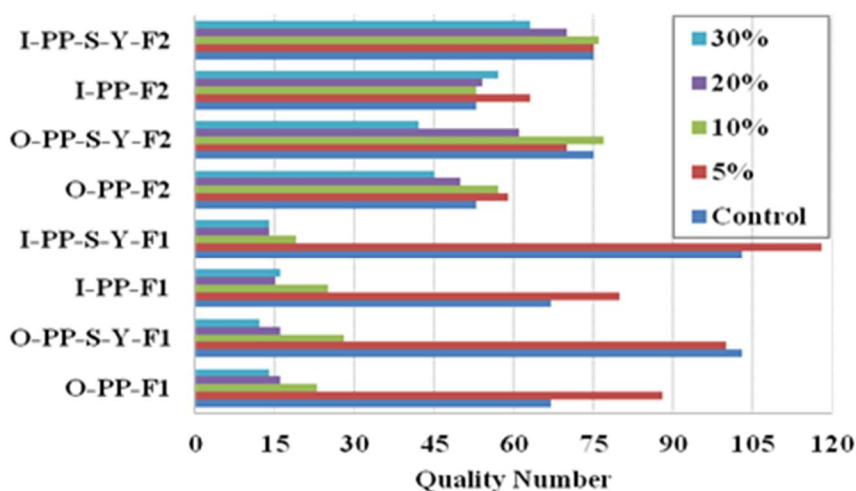


Figure 2. The effect of potato pasta, salt(S) and yeast(Y) on dough Quality Number(QN): O-PP-F₁ replaced with potato pulp *Orchestra* variety; O-PP-S-Y-F₁ replaced with potato pulp *Orchestra* variety, salt and yeast, I-PP-F₁ replaced with potato pulp *Impala* variety; I-PP-S-Y-F₁ replaced with potato pulp *Impala* variety salt and yeast; O-PP-F₂ replaced with potato pulp *Orchestra* variety; O-PP-S-Y-F₂ replaced with potato pulp *Orchestra* variety,

salt and yeast; I-PP-F₂ replaced with potato pulp Impala variety; I-PP-S-Y - F₂ replaced with potato pulp Impala variety salt and yeast

As shown in Figure 3, the best results were obtained for the batches with 5%, 10% and 20% potato content. The highest score belongs to the bread made with Orchestra potato, namely 18.5 points, in the batches with 20% PP. The other properties are similar to those of the bread made with Impala potato, except the taste. The addition of sugar components leads to the darkening of the bread crust due to caramelization. The components that contribute to changing the colour of the crust are in this case the products of protein hydrolysis (amino acids) and those of polysaccharide hydrolysis (fermentable sugars) that yield colored compounds (Maillard reactions)(Capuano *et al.*, 2008). The addition of potato pulp has negative effects on the elasticity of the bread crumb but improves the flavor and the taste (Kucerova *et al.*,2013). Therefore, the addition of PP enhances all the bread characteristics, including the fact that the bread crumb is less crumbly, but not to the detriment of elasticity, especially in the F₂ bread sample.



Figure 3. Macroscopic characteristics of bread supplemented with potato pasta

It was observed that the amount of water eliminated was lower in the case of dough without potato supplements when baked at the same temperature. The water binding behavior of the potato dough is different from that of the potato-free dough. Rheological properties do not predict the quality of the bread. The flourgram shown in figure 4 does not predict a level of bread quality similar to that obtained particularly for the batch with 20% PP. Gluten content decreases. This type of protein specific to wheat flour contributes to the structure formation. It is responsible for

dough elasticity and extensibility. These properties enhance the quality of the bread (Gallager *et al.*, 2003). The potato contains amyolytic enzymes, so it can help improve bread quality (Greene and Bovell, 2004). Therefore, the other macromolecular component presented in this study (namely, the starch) within the system where it was naturally produced contributes to improving the quality of the bread.

Bread crumb moisture is very important. Figure 5 shows an increase in bread moisture corresponding to the increase of the amount of potato pulp replacing flour in the bread making process. The increase in bread moisture in the control sample as compared to the batch with 30% PP addition was 8.7% in O-PP-F₁ bread and 12.2% in I-PP-F₁ bread. The increased bread moisture was 14.3% for F₂ with added Orchestra potato and 13.6% for F₂ with added Impala potato.

$$Y_{I-PP-F_1} = 1.35X + 42.67; r = 0.9222 \quad (1)$$

$$Y_{O-PP-F_1} = 1.02X + 43.5; r = 0.9548 \quad (2)$$

$$Y_{O-PP-F_2} = 1.57X + 39.85; r = 0.9776 \quad (3)$$

$$Y_{I-PP-F_2} = 1.35X + 42.67; r = 0.9884 \quad (4)$$

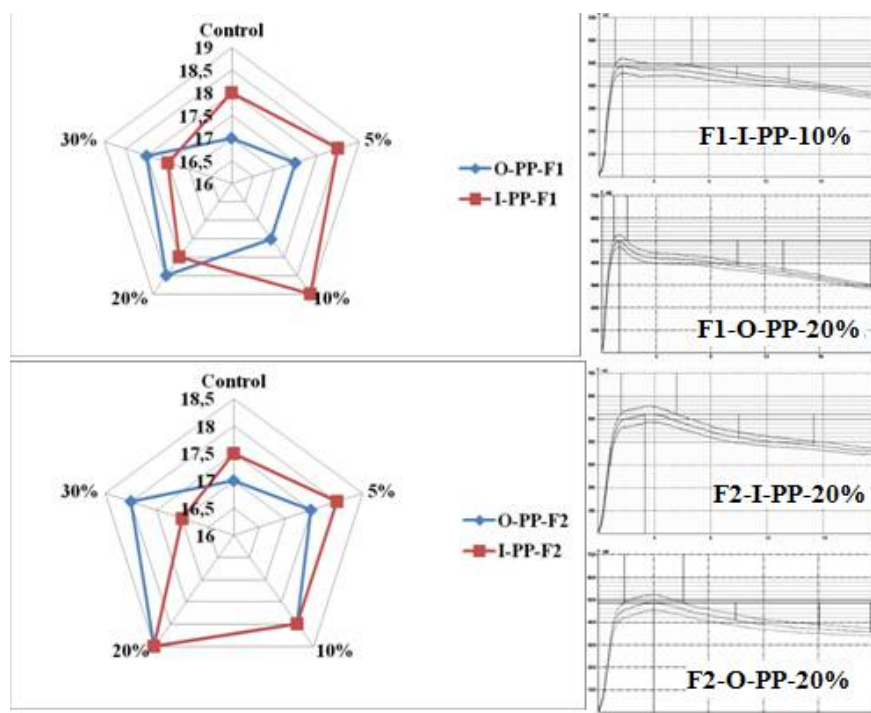


Figure 4. Spider plot of the effect of potato pasta on the selected sensory characteristics of bread (in points)(left) and profile diagram(flourgram) from dough with potato pasta(right)

When analyzed statistically, the regression equations obtained (1; 2; 3; 4) show a linear dependence to the positive indices of the former. The value of the correlation coefficient obtained is close to 1, which is positive and strong. The added PP brings about an increase in bread moisture and changes in bread texture.

Changing starch fractions in bread

The bread recipe analyzed in this study was developed by flourgraphic studies and contains two components which are rich in starch: wheat flour and boiled potato. A dose of 17-30g of RS is needed to enhance the physiological benefits of this type of dietary fiber (Cummings, *et al.*, 1996). According to other authors, one should ingest 10g of RS for its physiological benefits to become obvious (Higgins, *et al.*, 2004). The RS content of white wheat bread is 1.2 to 4.4 g/100g and that of high fiber white bread is 0.9 g/100 g. Boiled potatoes contain 1.3 to 4.5 g/100 g of RS, baked potatoes 1.0 g/100 g, and French fries 2.8 to 5.5 g/100 g (Murphy *et al.*, 2008).

In this study, the RS content was related to the dry matter content (Figure 6). The RS content of O-PP was 2.2 g/100 g d.m., out of a total of 16% (total content of potato starch) and that of F₁ flour was 1.1 g/100 g d.m. out of a total starch content of 76% in 100 g of sample. The RS content of I-PP was 2.3 g/100 g d.m. from a total of 14% starch content. Bread made from a combination of the two materials had the highest content of RS in the batch with 30% potato pulp replacing flour. Thus the RS content in bread was: RS – 3.79 g/100 g d.m. – O-PP-F₁, with moisture 48.7%; RS – 5.61 g/100 g d.m. – I-PP-F₁, with moisture 50.3%.

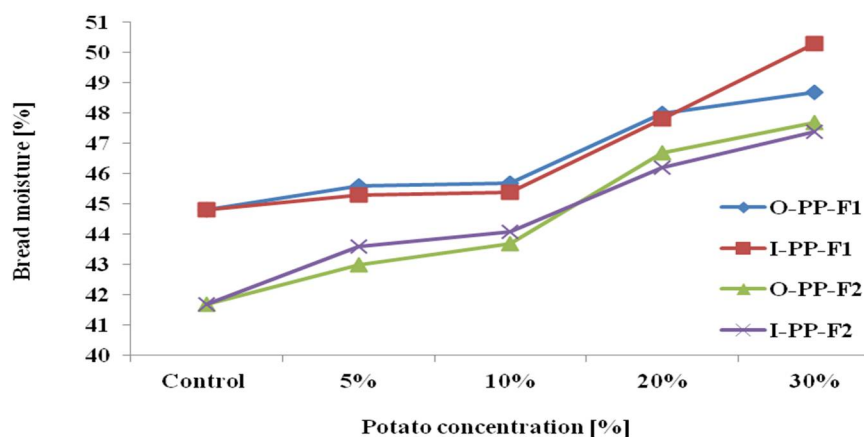


Figure 5. The moisture of products with different types and content of potato pasta and wheat flour

We observed that the RS content in durum wheat semolina flour (F2) was 3.1 g/100 g d.m. of a total of 78.8% starch in 100 g of the sample. The bread made from a combination of the two raw materials had the highest content of RS in the batch with 30% potato pulp replacing flour. Thus the RS content in semolina flour bread was as

follows: RS – 5.11 g/ 100 g d.m. – O-PP-F₂, with moisture 47.7%; RS – 3.7 g/ 100 g d.m. – I-PP-F₂, with moisture 47.4%.

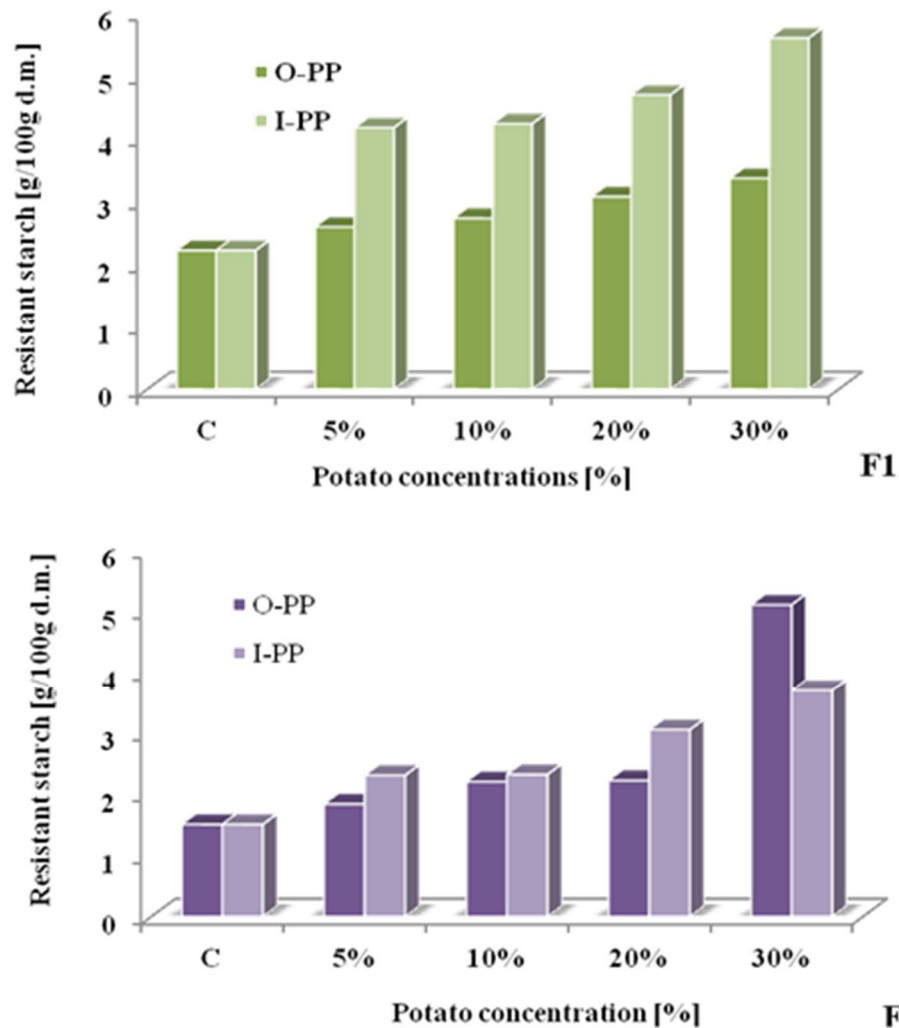


Figure 6. The Resistant starch of products with different types and content of potato pasta (O-PP, I-PP) and wheat flour (F₁ and F₂)

The processes and techniques used in bread making are based on operational parameters and conditions conducive to producing resistant starches. According to the National Health and Nutrition Examination Surveys, 1999-2002, adults should ingest 3.4 to 9.8 g of RS a day in order to ensure the necessary content of soluble dietary fiber. Therefore, potato bread may be seen as a good choice from this point of view. In Australia, for instance, potatoes, followed by bananas, are considered the

top sources of RS. In the United States, on the other hand, an amount of 3-8 g/person/day is considered acceptable (Murphy *et al.*, 2008).

The n-RS content for the batch with 5-20% potato content was increased in some samples of bread made from F₁ flour. This type of flour had a RS content of less than 1.2 g/100 g d.m., out of a total of 76 g/100 g d.m., as compared to F₂ with a RS content of 3.1g/100 g d.m., out of a total of 78,8g/100 g d.m. An overall decrease in n-RS content was found to occur with the increase in the amount of potato pulp replacing flour in bread making. As shown in Table 3, the TS content in potato bread generally decreases. The TS content also depends on the potato variety used. In this case, bread made with Impala potato showed an increase in TS content from 83.04 g/100 g d.m. to 86.23 g/100 g d.w. in F₁ and from 84,55g/100 g d.m. to 89.93 g/100 g d.m. in F₂.

The starch fractions are influenced by the potato variety used, as well as by the thermal treatment received before use. The cooling treatment and the freeze-thaw cycle do not seem to have such a big impact. As Mishra *et al.*, (2008) said, and his conclusion is confirmed by this study, the degree of fineness of the boiled potato pulp and the mechanical kneading (producing dough) are factors that influence the proportions of starch fractions. Drying, and the heat treatment needed to turn a piece of dough into bread seem to have the greatest influence on modifying starch fractions. The *in vitro* analysis used to determine the proportions of starch fractions is very appropriate because it is a sensitive method for easily digestible foods such as potato bread. Given the method of analysis used, RS may be a mixture of RS₂ (natural granule starch) and RS₃ (retrograde or non crystalline retrograde).

Table 3. The non resistant starch and total starch of products with different types and content of potato pasta (O-PP; I-PP) and wheat flour (F₁ and F₂)

Type bread ^a	n-Resistant starch [g/100 g d.m.]		Total starch [g/100 g d.m.]	
	O-PP ^d	I-PP ^e	O-PP ^d	I-PP ^e
F ₁ ^b				
Control	69.2862	69.2862	71.515	71.515
5%	84.045	74.5065	86.6483	78.6906
10%	81.0787	84.3846	83.8196	88.6323
20%	76.6019	80.3368	79.6887	85.044
30%	74.2821	69.6592	77.6609	75.2713
F ₂ ^c				
Control	83.0485	83.0485	84.5537	84.557
5%	69.1971	72.6671	71.0357	74.9749
10%	58.7733	74.7325	60.9772	77.0545
20%	57.7785	82.1965	60.0034	85.2495
30%	57.4062	86.235	62.5167	89.9359

^a -variant of work (control, flour was replaced with potato pulp at a rate of 5%, 10%, 20%, 30%.); ^b - the wheat brown flour type 1250; ^c - the semolina flour from durum wheat; ^d - F₁ or F₂ replaced with potato pulp Orchestra variety; ^e F₁ or F₂ replaced with potato pulp Impala variety;

Conclusions

The rheological properties of dough show values similar to those of poor quality flour. However, it was observed that the bread quality in batches with the same amount of PP was very good. Yet, the quality of the bread is enhanced by the other macromolecular component that is pre-gelatinized potato starch, as well as by the other components of this natural mixture. Although the results of the flourgraphic tests were similar to those of poor quality flour, the sensory analysis results indicated an improvement of the bread quality. The analysis proved that the WA levels decreased by 28.8% (F₂-I-PP), to 41.2% (F₁-I-PP). The development time and the dough stability also decreased, while dough softening was improved. Potato bread with 5, 10, 20, 30% PP content and F₁ and F₂ flour content was assessed in terms of its physicochemical and sensory properties. The screening test results indicate an increase in humidity of up to 50.3% (I-PP-F₁) and 47.7% (O-PP-F₂). The level of the ten analyzed sensory properties led to the conclusion that addition of up to 20% PP enhances bread quality. The addition of a higher percentage of PP improves bread crust colour but decreases the value of the other analyzed properties. As studied, the formation of RS in potato bread is influenced by the physicochemical characteristics of the dough, by drying (baking), by the percentage of the PP replacing flour, as well as by the potato variety and the type of flour used. The proportion of starch fractions is different in potato bread. Typically TS and n-RS levels decrease and RS levels increase. RS content is a mixture of RS₂ (natural granule starch) and RS₃ (retrograde or noncrystalline retrograde).

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