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Development of oat based-food formulation and quality characteristics

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Abstract

This study aimed to develop oat-based food by using oat bran and whole oat flakes. For this purpose a waffles formula was developed by substituting the wheat flour with different levels of oat bran (30%, 50%, 80%), while oat flakes were incorporated at different levels (10%, 15%, 20%) into snack bars formulation. The proximate composition (moisture, ash, fat, fiber, protein, carbohydrates) of the raw materials and oat-products was analyzed. The microbiological stability until 60 days and the consumer acceptance for the waffles and snack bars were also investigated. The oat bran and the whole oat flakes enrichment contributed to a higher fiber and mineral content in both developed product. The microbiological parameters of the oat-based waffles were within acceptable limits, while for the snack bars, after 60 days of storage at room temperature the yeasts and molds counts exceeded the limits. The oat products addition didn't impair the consumer acceptance.

Keywords: oat, waffles, snack-bar, quality characteristics

1. Introduction

Oats (*Avena sativa*) have several unique properties that make their milling different from other cereal grains [1] – their hull is not connected to the endosperm, they have a higher fat content than most cereal grains and they contain high levels of soluble dietary fibers [2]. The oat is most commonly processed as a whole grain because its groat is softer than other grains such as wheat, and thus cannot be easily converted into separate germ, endosperm and bran fractions. The outer layer of the groat is an important source of protein, neutral lipids, β-glucan, phenolics and niacin, and is sometimes separated from the groat to produce oat bran [2]. The inner endosperm consists of proteins, starch and β-glucan while the germ contains mainly lipids and proteins [3]. There are numerous steps in the milling process, the most important of which are dehulling to expose the digestible groat, heat processing to inactivate enzymes that cause rancidity, and cutting, rolling or grinding to convert the groat into a product that can be rapidly cooked and/or incorporated into other food products [4]. So, the main products obtained after oats processing are oat flakes, oat flour, oat bran, concentrated β-glucan, oat hulls etc. [3,5].

Bran is the edible, outermost layer of the oat kernel and is produced by grinding clean groats or rolled oats for separating the resulting flour by sieving, bolting and other suitable means into fraction such that the oat bran is not more than 50% of the starting material. It has total β-glucan and dietary fiber not less than 5.5 and 16.0% respectively with at least one third of total dietary fiber is soluble fiber [2]. Oat bran contains 17.1% protein, 67.9% carbohydrates, 8.6% fat, 15– 22% dietary fiber, 10.4% β-glucan, 1.3 mg niacin, 171 mg magnesium, 6.4 mg iron, 0.17 mg

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copper, 441 mg potassium and α-tocopherol less than 0.5 mg [6].

Whole oat groat contains high amounts of valuable nutrients such as soluble fibers, proteins, unsaturated fatty acids, vitamins, minerals, and phytochemicals. The dietary fiber complex with its antioxidants and other phytochemicals is effective against cardiovascular disease and some types of cancer [7,8,9].

Oats dietary fiber has important component β-D-glucan. Purified oat β-glucan is linear, un-branched polysaccharide composed of 1-4-*O*-linked (70%) and 1-3-*O*-linked (30%) β-D-glucopyranosyl units. Different physiological effects of β-glucan are related to its viscosity: attenuation of postprandial plasma glucose and insulin responses [2], high transport of bile acids towards lower parts of the intestinal tract and high excretion of bile acids [10] or lowering of serum cholesterol levels [11,12].

In recent years, the market has showed marked interest in developing foods containing functional ingredients; therefore, the interest in oats has also expanded. Due to the increasing demand for healthier foods, the baking industry is directing its efforts towards functional foods development. Cereals offer an attractive alternative for the production of various functional foods such as baked goods, cookies or snack bars. Nutritional bars have become a solution for lunch boxes, fast on-the-bus breakfasts, and after-school snacks. Bars are not just popular because of their portability, however. They have also become popular because of the health connotations associated with them. Health and wellness is a trend being marketed by nearly all major food and drink products, including 'ready-to-eat cereals, cereal bars and health bars'[13]. Oats are cereal grains that are commonly accepted by consumers globally. They appear in a wide range of food products, including low-energy beverages, medical foods, baked goods and granolas. In a time of increasing global food-security issues and dual health burdens of overweight and underweight, oats could be part of inexpensive, nutritious products for the future[14].

This study aimed to develop oat-based food by using two types of processed oat, namely oat bran and whole oat flakes in order to obtain functional food with improved nutritional and sensorial quality. For this purpose a waffles formula was developed by substituting the wheat flour with different levels of oat bran (30%, 50%, 80%), while oat flakes were incorporated at different levels (10%, 15%, 20%) into snack bars formulation.

2.Materials and methods

All raw materials needed for formulating waffles and snack bars were purchased from the local market.

*2.1 Waffles preparation.*Waffles were produced in four experimental variants by substituting wheat flour with different levels of oat bran (0-80%) as seen in table 1. The amounts of other raw materials used for the four experimental variants (W0-W3) were: shortening-olive oil (32%), sodium bicarbonate (0.8%), salt (1,5%), dried vegetables powder (5%) and water (200%). The main parameters of the wheat flour used for waffles formulation were 0.510 % ash content, 13.48% moisture content and 11.28% protein content (% dry matter). The ingredients were mixed thoroughly in a Hobart mixer. In order to obtain a pattern (grid like) with deep indentation on each side, the batter was formed in a metal appliance and baked with the waffle iron at 350˚C for 3 min, using a cooking machine. Finally, the waffles were cooled at room temperature, packed in aluminized aseptic bags, sealed and stored in cool and dry place.

Table 1. Experimental blends obtained by replacing wheat flour with oat bran

Ingredients	Waffle formulations			
%	W0	W1	W2	W3
Wheat flour, WF	100	70	50	20
Oat Bran, OB	-	30	50	80

2.2 Snack bar preparation. Three experimental variants (S1, S2, S3) of snack bars were prepared adding different levels of whole oat flakes (10%, 15%, 20%) calculated as percentage from the amount of a batch (table 2). The flow-sheet for the snack-bar preparation is presented in figure1. The samples were prepared by mixing the wet ingredients, heating the sucrose-glucose-corn syrup (80˚Brix) to boiling temperature and thoroughly blending with the premixed dry ingredients. The resulting mixture was weighed, pressed into rectangular bars (25mm×75mm×10mm) and allowed to cool at refrigerated temperature for 6h. Finally, the cereal

bars were packed in aluminized aseptic bags, sealed and stored in cool and dry place.

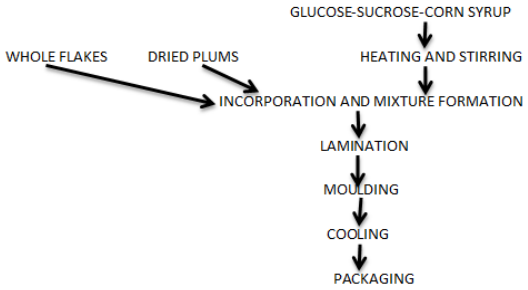

Figure 1. Flow-sheet for snack-bars production

Table 2. Snack bars formulations (S1-S3) obtained by using different amounts of oat flakes (10%, 15%, 20%)

Ingredient	Snack bar formulations		
%	S1	S2	S3
Whole oat flakes	10	15	20
Dried plums	50	45	40
Grounded walnuts	13	13	13
Glucose-corn syrup	7	7	7
Sugar	20	20	20

*2.3 Proximate composition analysis.*The proximate composition of the oat bran, whole oat flakes, waffles and snack bars was analyzed. The moisture, ash, crude fat, crude fiber and protein (N×6.25) contents were determined according to standard methods [15]. The content of available carbohydrates was determined by difference from the protein, fat, moisture, ash and crude fiber contents. All experiments were performed on three replicates.

2.4 Microbiological stability. The microbial stability of waffles and snack bars was evaluated according to the specifications of the [16]. The microbiological stability of these products was evaluated in triplicate during 60 days (0-30-60) of storage at room temperature by analyzing the total viable aerobic mesophilic bacteria, *Escherichia coli, Bacillus cereus, Staphylococcus aureus*, yeast and mold counts. Also the presence of *Salmonella sp*, coliforms was verified. All measurements were performed in triplicate.

2.5 Sensorial analysis. A total of 50 untrained panelists (students and faculty staff with ages between 20-58) were used to evaluate the waffles and snack bars. Samples were presented on white plastic plates at room temperature and assessed for overall acceptability, appearance, color, taste and texture. Evaluations were conducted using a nine-point hedonic scale to determine the degree of liking (9-like extremely, 5-neither like nor dislike, 1-dislike extremely).

2.6 Statistical analysis. Analysis of variance (ANOVA) was used to determine whether there was a statistically significant difference significant difference between samples.

3.Results and discussion

The mean values for the proximate chemical composition of the oat bran and oat flakes are shown in figure 2. As seen in figure1 both, oat bran and oat flakes, showed valuable contents of ash, crude fiber, crude fat and protein. Oat bran showed an improved content of crude fat (8.21%) and protein (16.25%) compared with the oat flakes. The oat bran crude fat content was 1.6 times higher than in the oat flakes, while the protein content was 1.2 times higher. Oat bran and oat flakes contents in ash and crude fiber were quite similar. Luhaloo et al. (1998) [17] reported that commercial oat bran collected from five different countries showed wide variations in the content of crude protein (9.6–21.0%), crude fat (8.2–12.0%), ash (2.0–4.1%). Manthey et al., 1999,[18] reported for hulled oat a contain of 10–12.1% fiber, including 4.1–4.9% soluble fiber and 6.0–7.1% insoluble fiber, 16.89% of protein. Xin-Zhong Hu, 2014 [19] and Lapveteläinen and Rannikko, 2000 [20] reported several factors which could contribute to differences between samples chemical content such as: different areas, different planting time, different varieties, manufacturing conditions, climate condition, soil, and fertilizer.

The mean values for the proximate chemical composition for dried plums used into snack bars formulation were moisture 23.2%, protein 2.6%, crude fat 0.5%, crude fiber 6.1% , ash 0.9 % and total carbohydrates 62.7%. Results are consistent with [21]. The mean values of proximate composition of oat-based developed products are given in table 3. The moisture content of waffles ranged between 3.25% (W0- control sample) and 4.32% (W3-sample with 80% OB). Addition of OB at increasing levels from 30% to 80% produced a slight increment in moisture content, as seen in table 4, and it can be attributed to the water holding capacity of OB fibers.

This moisture content assure a good microbiological stability for waffles during storage period (as seen below).

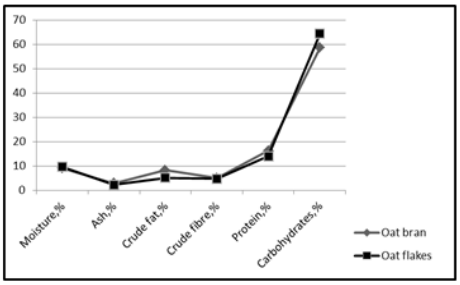

Figure 2. Proximate chemical composition of oat bran and oat flakes

The data on crude fat content of waffles show non-significant changes ($p>0.05$) with the increment of OB content. The value of the crude fat content in waffles (W1-W3) could be rather associated with the olive oil used in their formulations. Increased amounts of OB from 30% to 80% produced significant changes ($p<0.05$) in ash, crude fibers and protein content of waffles. As we expected, waffles with 80% OB recorded the highest content in ash (3.10%), crude fiber (4.34%) and protein (12.56%).

With respect to the snack-bars, the increasing addition of oat flakes in snack-bars (S1-S3) didn't affect significantly the moisture content of products (table 3). Mainly, the high moisture content of the snack-bars samples is due to the dried plums humidity (23.2%). Similar results were found by [22, 23] who reported the contribution of dried fruits to the moisture content of bars. The ash, crude fiber and protein contents of snack-bars were significantly ($p<0.05$) affected by the increased addition of the oat flakes. Sample S3 (20% oat flakes) recorded the highest contents in ash (1.62%), crude fiber (5.45%) and protein (7.87%) between all samples (S1-S3). We could notice that snack-bars with 15% (S2) and 20% (S3) oat flakes registered relative high content of protein. Similar results were reported by [24], for cereal bars with murici-pass the protein content ranged between 6.93% and 7.49%. Gutkoski et al. (2007) [25] reported values ranging from 9.79 to 12.37% for oat based cereal bars with high content of dietary fiber. The ash content of the snack-bars ranged between 0.98% and 1.62%. These values were similar to results reported by other researchers for different types of cereal-fruits bars as following: 1.13 % [26]; 1.40 – 1.61% [27]; 1.15 to 1.38 [24] and 1.29-1.30% [28]. The crude fiber content of the snack-bars formulations (S1-S3) ranged between 4.97%-5.45%; Santos et al., 2011[29] reported ash contents ranging between 4.10-4.60% for cereal-bars with jackfruit., while [22] developed apricots-date bars with around of 5.85% crude fiber content. The crude fat content of the snack-bars was associated with the addition of the walnuts, as mainly contributor, and secondary, with oat flakes addition. According to the food composition database published by the US Department of Agriculture, 100 g of walnuts contain 15.2 g protein, 65.2 g fat, and 6.7 g dietary fiber. Whereas most nuts are high in monounsaturated fatty acids, walnuts are composed largely of polyunsaturated fatty acids (47.2 g), especially α -linolenic acid (18:3n−3; 9.1 g) and linoleic acid (18:2n−6; 38.1 g) [30].

All oat-based food products developed in this study were negative for *Salmonella sp*., coliforms, *Staphilococcus aureus, Bacillus cereus* and *Escherichia coli*. The evolution of the microbiological profile of the samples during storage until 90 days was also analyzed. All the waffles samples met the standard set for specific recommendations of Romanian regulation for each category and did not present exceeding microbiological limits for 0, 30 and 60 days. Oat based-waffles presented a regular profile in the yeast and mold count ranging from 10 cfu/g to 50 cfu/g.In the case of the snack bars samples after 30 days storage at room temperature the yeast and mold count was 5.4 x 10 cfu/g, while after 60 days of storage this count was 1.46 x 10^3cfu/g, exceeding the limits. The growth of molds and yeast in the snack bars after 60 days of storage at room temperature is related to the high moisture content found in these samples (as seen in table 4). According to [13,31] water activity has a profound effect on the rate of many chemical reactions in foods and on the rate of microbial growth. Moulds and yeasts will start to grow at a water activity between 0.7 and 0.8. Bacterial growth will take place when water activity reaches 0.8. For the conservation of these products additional studies, changing the packaging or the processing, coating or adding preservatives should be carried out.

Table 3. Proximate chemical composition of waffles and snack bars developed as oat-based food

	Waffles				Snack bar		
%	W0	W1	W2	W3	S1	S2	S3
Moisture	3.25	3.46	3.91	4.32	21.65	23.41	24.43
Ash	2.16	2.39	2.71	3.10	0.98	1.12	1.62
Crude fat	11.33	11.49	11.61	11.78	10.78	11.05	11.23
Crude fiber	1.24	2.15	3.21	4.34	4.97	5.25	5.45
Protein	7.90	9.87	11.01	12.56	5.74	6.91	7.87
Total Carbohydrates	73.67	70.52	67.67	64.35	55.88	52.27	49.26

Mean values of three independent determinations; for details see Materials and methods section

Table 5. Sensory attributes for waffles and snack-bars

	Overall acceptability	Aroma	Color	Taste	Texture
W0	5.9	5.4	6.5	5.7	6.6
W1	6.1	5.5	6.8	6.2	6.8
W2	6.9	6.1	7.1	6.5	7.2
W3	7.1	6.2	7.5	6.8	7.2
S1	6.2	6.8	6.5	6.4	5.2
S2	6.9	7.2	6.9	6.9	5.5
S3	7.0	7.2	7.1	6.9	5.8

Mean values of three independent determinations; for details see Materials and methods section

The consumer acceptance of oat-waffles formulations (W1-W3) did not significantly differ ($p>0.05$) but significant differences ($p<0.05$) were found between the control sample W0 and the formulation containing the major amount of oat bran (W3, 80%), suggesting that the presence of the oat bran favorable influenced the sensorial quality of these types of products (table 5).

From all formulation, sample W3 recorded the highest values for all the sensorial attributes (aroma, color, taste and texture) and consequently for the overall acceptability. In our opinion this pattern could be the contribution of the oat bran which produced a positive impact on the sensory attributes, specifically on the color and texture.

In the case of snack-bars formulation, samples S3 (20% whole oat flakes) recorded the highest values for the overall acceptability, as well as for all sensorial attributes but without significant differences between formulations (S1-S3). These results demonstrated that the utilization of oat bran and oat flakes did not affect negatively the consumer's acceptability of oat-based products, namely waffles and snack-bars. The texture of the snack-bars recorded the lowest scores from all the sensory attributes. We consider that it could be due to the high moisture content of the samples. If for the commercial snack-bar the moisture content ranging between 1-7% and generating a "crispy" type of product, in the case of our study a soft type of snack-bar was developed and that could be the reason of a lower scoring.

4. Conclusion

In this study two types of oat-based products were developed by using oat bran and oat flakes in the formulations of waffles and snack-bars with dried plums. The study showed that addition of oat bran up to 80% in waffles formulation is possible in order to develop product with good quality characteristics. Also, a mixture of oat flakes: dried plums up to 20:40 (%) lead to a snack bar with improved nutritional and sensorial characteristics. Both products showed good sensory and nutritional values by providing high amounts of fibers, minerals and proteins.

Compliance with Ethics Requirements. Authors declare that they respect the journal's ethics requirements. Authors declare that they have no conflict of interest and all procedures involving human / or animal subjects (if exist) respect the specific regulation and standards.

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