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UTILIZATION OF WHOLE RYE GRAINS IN BISCUITS MANUFACTURING

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ABSTRACT

Whole grain products are recommended for healthy diets as being recognized sources of dietary fiber and antioxidant substances. In the present study, whole rye grains flour are adapted to mix with wheat flour (72% extraction) in a partially (25, 50 or 75%) or completely substitution (100%) to prepare a high favorable acceptable biscuits. The prepared biscuit were compared with the control sample (rye flour free) regarding to their chemical, nutritional and sensory properties.

The adapted biscuits exhibited better chemical, physical, nutritional and sensory evaluation compared to control sample. They were significantly rich in total dietary and crude fibers, protein, ash, β-glucan fractions and minerals. It is recommended to substitute wheat flour (72% extraction) with whole grain rye flour up to 50% ratio, wherein, they were the most favorite utilized substitutions with respect to the tested physical and sensory evaluation attributes.

Keywords: whole rye flour; chemical, physical and sensory, biscuits.

INTRODUCTION

In some countries, Northern and Eastern Europe, rye is a traditional cereal that is generally used as whole meal flour in both soft and crisp breads (Nilsson *et al.*, 1997). It can also grow and give higher and more stable grain yields in regions characterized by low rainfall or drought, high temperature and low soil fertility. In other words, they perform well under poor soil and growing conditions (Ragaee *et al.*, 2006). The environment and climate in the United Arab Emirates (UAE), as well as KSA, are characterized by such conditions, and thus adaption of these cereals is of great interest. In the development and introduction of these crops to such countries, there is a need to evaluate their nutritional quality and potential uses (Ragaee and Abdel-Aal, 2004).

Recent studies (Juntunen *et al.*, 2000; Karppinen *et al.*, 2003; Rieckhoff *et al.*, 1999) have shown that cereal grains contain constituents that have demonstrated health benefits for humans, such as antioxidants and anti-disease factors. For instance, phytic acid was found to play a major role in the treatment of cancer, hypercholesterolemia, hypercalcuria and kidney stones (Plaami, 1997). Other studies have also demonstrated that diets high in carbohydrate, rich in dietary fiber, and largely of cereal origin, allowed withdrawal of oral hypoglycaemic agents or a reduction of insulin dose in diabetic subjects (Pathak *et al.*, 2000). Additionally, several health claims on grain dietary components have been approved by the FDA in the USA. Keeping in mind the necessity for increasing dietary fiber and other bioactive dietary components in the diet, additional plant food sources are needed. Whole grain products have the potential to make a good contribution in this respect as recognized sources of dietary fiber, minerals, vitamins, and antioxidants.

Although the total production of rye has diminished, its use as a food for humans increased slightly during the 1990s. In 1995, the worldwide food consumption of rye accounted for about 8 million metric tonnes, which is about 35% of the total production (Bushuk, 2001). The rest was used as feed. Rye grain, like other cereal grains, contributes significant quantities of energy, protein, selected micronutrients and non-nutrients to a human diet (Edge *et al.*, 2003). Rye is an excellent raw material for healthy and tasty foods and it has high fiber content. The whole grain contains a large variety of substances, especially those that are biologically active and demonstrate antioxidant properties, which include free radical-scavengers, reducing agents, potential complexes of prooxidant metals and quenchers of the formation of singlet oxygen (Zieliński, 2002). Cereal and cereal-based foods, including rye grain, represent the bulk of all foods consumed. However, their contribution to human nutrition and health should be considered cumulative and collective, together with the consumption of fruits and vegetables (EU-Air Concerted Action, 1998). The latest clinical evidence shows that the consumption of whole foods, such as fruits, vegetables, and whole grain products, and not just their known purified antioxidants, is correlated with a reduced risk of chronic diseases (Willcox *et al.*, 2004).

The flours of different grains, such as wheat and rye, are commonly used to produce weaning cereal foods for infants. However, the nutritional quality is low in these cereal raw materials, hence, they have to be processed to improve their nutritional quality and acceptability to infants (Pérez-Conesa *et al.*, 2002). Infant cereals are often the first complementary weaning foods; therefore, high quality cereals are necessary, in order to satisfy the baby's special growing needs. Infant cereals have a high energetic load, based on their carbohydrate and protein contents of approximately 78% and 13%, respectively (Frontela *et al.*, 2008). Different processing steps could be done for improving their sensory qualities, digestibility, safety and shelf-life (Ramirez-Jimenez *et al.*, 2003) and enhancing the bioavailability of functional factors after intake (Davidsson *et al.*, 1997). Good nutrition of infant foods is essential during the critical period of infancy to promote optimal growth and development of infants (Raiha and Axelsson, 1995). Diet structure, especially in childhood and adolescence, influences not only the immediate health of children, but may also have an important impact on adult health. (Camara *et al.*, 2005). For instance, insufficient mineral intake in the first year of life is responsible for diseases, such as iron deficiency anemia, rickets, osteoporosis, and immune disease (Frontela *et al.*, 2008). Although processing can increase cereal protein digestibility, protein quality of infant cereal foods is usually improved by mixing different kinds of cereals together.

Many studies indicate that foods containing substances rich in antioxidant activity may also prevent many diseases and promote good health (Temple, 2000; Willet, 1994) because reactive oxygen species and other free radicals play an important role in many degenerative diseases (Beckman and Ames, 1998). Infant cereal foods enriched with antioxidants are likely to have the potential for infant disease prevention and health promotion. They are probably valuable for the enhancement of the nutritional quality of infant cereals. In addition to good nutrition, favorable aroma plays a critical role in stimulating infant appetite and contributes significantly to infant enjoyment of foods (Kälviäinen *et al.*, 2003).

The main dietary fiber fraction in rye is arabinoxylan and it was reported that rye grains contain 9.1% arabinoxylan, 2.3% cellulose, 1.8% β-glucan and 1.2% Klason lignin (Aman *et al.*, 1997).

The objective of this study was to evaluate the chemical, physical, nutritional and sensory properties of biscuits manufactured by whole rye flour partially or completely substitution instead of wheat flour.

MATERIALS AND METHODS

Materials:

Whole Rye (*Secale cereale* L) grains and 72% extraction rate wheat flour (*Triticum aestivum* L.) were obtained from National Company for the Manufacture of Biscuits and Sweets, "Tamu" in Jeddah, , Kingdom of Saudi Arabia (KSA). The other biscuit ingredients (sugar, milk powder, butter milk, vanilla, lecithin, salt, ammonium bicarbonate and glucose) were obtained from local market at Jeddah, KSA.

The rye grains were ground using a Cyclone Sample Mill (UDY Corp., Fort Collins, CO) equipped with a 1.0 mm screen. The whole grain meal and wheat flour samples were kept in a refrigerator until analysis.

Methods:

Preparation of the tested biscuits:

The biscuit samples were prepared according to the standard procedure method for semi hard sweet biscuit manufactured at National Company for the Manufacture of Biscuits and Sweets, "Tamu" in Jeddah. The utilized formula ingredients are found in Table (1). Exactly 25, 50, 75 and 100% wheat flour (72% extraction rate) were substituted by resemble amounts of whole rye flour.

Determination of physical properties:

The purity percent of the rye grains was calculated by inspection of specified amount and divided the true rye grain number by the whole grain specified amount and multipled by 100. One thousand kernel weight (TKW in g) of rye grain was determined by weighing 100 seeds in four replicates as described by (Soylu and Tekkanat 2007). Specific weight (kg/ Hectoliter), specific volume (cm^3/g), volume (cm^3), weight (g) and density (g/cm^3) were estimated as suggested by Manohar and Rao (1997).

Determination of chemical compositions:

Whole rye grains meal and wheat flour samples were analyzed for moisture, ash, fiber and fat according to the Approved Method of the American Association of Cereal Chemists (AACC, 2003). The protein content was expressed as Nitrogen (determined by micro kjeldahle method) multiplied by a factor depending on the type of cereal (5.83 for rye) and the Carbohydrates were calculated by differences (Ragaee *et al.*, 2006).

All the final products (biscuit samples) were subjected to the chemical composition (moisture, protein, fat, ash, fiber and Carbohydrates, calculated by differences) as recommended by AOAC (1990). Mineral contents (iron, calcium, zinc, magnesium, manganese, sodium and potassium were determined using a Pye Unicum SP1900 Atomic Absorption Spectroscopy instrument (Perkin Elmer model 4100ZL) as described by AOAC (1990).

Table (1): The Formula ingredients (in Kg) of the tested biscuit samples

Ingredients (in kg)	Control sample	Rye flour replacement %			
		25	50	75	100
Wheat flour (72 %)	250	187.5	125	62.5	250
Whole rye flour	0.00	62.5	125	187.5	0.00
Sugar	70	70	70	70	70
Milk powder	6.300	6.300	6.300	6.300	6.300
Butter milk	60	60	60	60	60
Vanilla	0.30	0.30	0.30	0.30	0.30
Water	30	30	30	30	30
Lecithin	0.350	0.350	0.350	0.350	0.350
Salt	1.20	1.20	1.20	1.20	1.20
Ammonium bicarbonate	6.50	6.50	6.50	6.50	6.50
Glucose	11	11	11	11	11

Determination of dietary fiber:

Total dietary fiber contents were quantified using the enzymatic gravimetric procedure of the AACC Method 32–07 (AACC, 2003). Arabinogalactan from Sigma was used as a standard reference for the determination of total dietary fiber, giving accuracy of 95.3%.

Determination of β-glucan fractions:

β-glucan fractions (soluble, nonsoluble and total β-glucan) were determined as described by Gajdošová *et al.*, (2007) .

Estimation of the sensory evaluation:

The sensory evaluation of the tested samples attributes were determined by well trained panelists (15 judges) for general appearance, taste, color, odor, tenderness, porous distribution and palatability as suggested by Dhingra and Jood, (2001).

The statistical analysis:

Data analysis was statistically performed using SAS (1987) software. Analysis of variance was used to test for differences between the groups. Least Significant Differences (LSD) test was used to determine significant differences ranking among the mean values at P< 0.05.

RESULTS AND DISCUSSION

Physical properties of whole rye grains:

Rye (*Secale cereale* L.) is a widely grown cereal in northern, central and eastern Europe. Its main use for bread and other products making aimed for human consumption or animal feed (Kamal-Eldin *et al.*, 2008).Whole rye grains, used in the current study, are characterized by a strict high quality and purity (Table 2). Such finding is completely clear when detect that the rye kernel% in the utilized rye grains was 100%. The same Table shows also that the whole rye grains possess 1000 Kernel weight value of 42.86 g and Specific weight value of 57.14 g/Hectoliter. Therefore, it could be obviously considered and seemed to be large as defined by Ziegler *et al.*, (1984). Such kernel properties and characteristics are directly affected expansion volume and how much expansion volume and kernel properties variation was apparent in commercial processing. The larger kernel types contain a high percentage of soft endosperm and are preferred by vendors as large kernels produce larger flakes that have good eye appeal and are tougher, thus reducing breakage from handling even though they may have more hulls (Soylu and Tekkanat 2007).

Table (2): Physical properties of whole rye grain

Items	Value
Rye kernel %	100
1000 Kernel weight (g)	42.86
Specific weight (kg/Hectoliter)	57.14

Chemical compositions of whole grain rye flour:

Scientists of various specialties invest to highlight their new product and its industrial application through estimate their composition as nutrient sources (Giannelos *et al.*, 2005; Ramadhas *et al.*, 2005). With such point of view, Table (3) revealed that all the chemical composition, except carbohydrate) were significantly higher in rye flour than in case of wheat flour. On the other hand, the carbohydrate content was the main component (70.97%) of the whole grain rye flour. It could be, also, found that rye flour could be considered as excellent sources for the other ingredients such as, fiber, protein, minerals and fat. These components, and other components, reached an adequate amount (2.52, 12.76, 1.63 and 2.22%, respectively) enough to consider the rye flour to be nutritious component in preparing meal for different ages, infants, youths and elders in order preventing different diseases. Confirmed to such observation, different authors apply whole rye flour in different bakery product formulas for such purposes, Nehdi *et al.*, 2010; Wende *et al.*, 2010; Ragaee *et al.*, 2006; Lang and Jebb, 2003 and Adams and Engstrom, 2000).

Table (3): Chemical compositions of whole rye grains and wheat flour (% as dry weight basis)

Components	whole rye grain flour	Wheat flour
Moisture	9.6	13.1
Protein	12.76	10.35
Carbohydrates	70.97	87.44
Fat	2.22	1.05
Fiber	2.52	0.47
Ash	1.63	0.69

Chemical compositions of biscuits manufactured by different ratios of whole rye flour:

Cereal and cereal-based foods, including rye grain, represent the bulk of all foods consumed. However, their contribution to human nutrition and health should be considered cumulative and collective, together with the consumption of fruits and vegetables (EU-Air Concerted Action, 1998).

Therefore, the rye grain varieties, which possess a high content of protein and ash and low starch content, seems to be more required for the cereal industry for further processing (Zieliński *et al.*, 2007). Applying to such idea, it was suggested in the current study to replace specified amounts of wheat flour, 72% ext. rate, (25, 50,75 and 100%) by the same amount of whole rye flour to prepare healthy biscuits . Data in Table (4) show the impact of such replacement on chemical compositions of the resulted biscuits. It referred to that all the tested parameters were positively increased affected due the replacement increasing, except of carbohydrate contents. In spite of such findings, 50 and 75% rye substitutions seemed to be significantly impact on the chemical and nutritious parameters than the control sample. On contrary, most tested components in 25% rye substitution were not significantly differed than the control sample and 100% rye substitution and were not significantly differed than the 50 and 75% rye substitution samples. In general, 50 and 75% rye substitutions could be considered a good tool to enhance the chemical and nutritious status of biscuits.

Table (4): Chemical compositions of biscuits manufactured by different ratios of whole rye flour (as g/100 g dry weight basis)

Biscuit samples	Moisture	Protein	Fat	Ash	Fiber	Carbohydrates
Wheat flour (72 %) Control	4.08	11.20	20.29	1.2	1.9	65.41
Wheat flour (72 %) + 25% Rye flour	4.34	11.55	18.89	1.90	2.50	65.16
Wheat flour (72 %) + 50% Rye flour	4.48	11.72	18.00	2.22	3.82	64.24
Wheat flour (72 %) + 75% Rye flour	4.55	11.78	17.63	2.45	4.25	63.89
100% Rye flour	4.75	11.88	17.00	2.66	4.50	63.96
LSD	0.22	0.46	0.12	0.65	0.84	1.2

Total dietary fiber and β-glucan fractions of biscuits manufactured by different ratios of whole rye flour:

Whole grains flour, including rye, are recommended for healthy diets as being recognized sources of dietary fiber and antioxidant substances. Some β-glucans are well-known biological response modifiers and the sources from which they are derived are widely distributed in nature and used in medicines and foods (Torello *et al.*, 2010). These substances are considered as biological response modifiers, which are recognized by the innate immune system. This recognition plays an important role in host defense and presents specific opportunities for clinical modulation of the host immune response. They increase host immune defense by activating complement system via the alternative activation pathway and by enhancing macrophages and natural killer cell function. In vitro studies have demonstrated enhanced microbial killing by monocytes and neutrophils in healthy volunteers after β-glucan administration (Akramienė *et al.*, 2007). Therefore, total dietary fiber (TDF) and β glucan fractions, total, soluble and insoluble, were put under investigation in the present study (Table 5). It was found that whole grain rye flour is a TDF rich source where in it was (25.45%) more than two folds of biscuit control sample (rye free) prepared only from wheat flour (11.65). it was concurrent with that found by Rakha *et al.*, (2010). On the other hand, the TDF amounts were significantly upwarded in the biscuit sample as a function of increasing the rye substitution ratios.

With respect to β glucan fractions, Table (5) shows, that each fraction was higher in the whole rye flour (2.43, 1.33 and 1.10, respectively) than that the corresponding one in the biscuit control sample (1.74, 1.07 and 0.67, respectively). Indeed, soluble β glucan fraction amount was more pronounced than nonsoluble fraction in both of whole rye flour (1.33 and 0.10%, respectively) and biscuit control sample (1.07 and 0.64%, respectively). Such results were agreed with that found by Izydorczyk *et al.*, (2008) who detected the higher β glucan content in rye flour. Consequently, all β glucan fraction amounts were significantly increased in the corresponding biscuit sample as a result of increasing the rye substitution ratios (Table 5).

Table (5): Total dietary fiber and β glucan fractions of whole rye flour and biscuits manufactured by different ratios of them (as g/100 g dry weight basis)

Biscuit samples	TDF	β glucan		
		Total	Soluble	Non Soluble
Whole rye flour	25.45 ± 0.01	2.43 ± 0.37	1.33 ± 0.33	1.10 ± 0.70
Wheat flour (72 %) Control	11.65 ± 0.01	1.74 ±0.39	1.07 ±0.40	0.67 ±0.79
Wheat flour (72 %) + 25% Rye flour	15.90 ± 0.10	1.86 ±0.62	0.92 ± 0.00	0.94 ± 0.75
Wheat flour (72 %) + 50% Rye flour	17.40 ±0.10	2.60 ± 0.20	1.32 ± 0.10	1.28 ± 0.10
Wheat flour (72 %) + 75% Rye flour	20.68 ± 0.01	3.22 ± 0.28	1.62 ± 0.35	1.60 ± 0.07
100% Rye flour	21.80 ± 0.10	6.24 ± 0.28	3.62 ± 0.15	3.62 ± 0.43
LSD	0.11	0.45	0.42	0.67

Mineral contents of biscuits manufactured by different ratios of whole rye flour:

Data presented in Table (6) show that all the tested minerals were significantly high in the whole rye flour than that found in the corresponding one in the biscuit control sample (rye free). Potassium, magnesium and calcium amount were the highest in both of whole rye flour reached 412.00, 92.00 and 31.50 mg/100g, respectively, while, biscuit control sample showed 160.00, 45.00 and 20.30 mg/100g, respectively, values. It was in parallel with that found by Ragaee *et al.*, (2006) who reported, also, that the nutritional data suggest that selected whole grains, including rye, hold promise as healthy food ingredients due to their phosphorus, calcium, potassium, magnesium, sodium, copper, iron and zinc content.

The current study, Table (6), showed that due to the higher mineral amounts in the utilized rye flour, compared to that found in control biscuit, each of substitution levels led to a significant impact on the corresponding resulted biscuit. Suggesting it is prefer to monitor the required mineral amount and apply the appreciate substitution amount.

Table (6): Mineral contents of biscuits manufactured by different ratios of whole rye flour(as mg/100 g dry weight basis)

Biscuit samples	Iron	Calcium	Zinc	Magnesium	Sodium	Potassium
Whole rye flour	3.70	31.50	3.25	92.00	0.90	412.00
Wheat flour (72 %) Control	1.32	20.30	1.26	45.00	0.13	160.00
Wheat flour (72 %) + 25% Rye flour	2.11	22.43	1.56	52.00	0.12	188.00
Wheat flour (72 %) + 50% Rye flour	2.32	24.55	1.67	65.00	0.11	300.00
Wheat flour (72 %) + 75% Rye flour	2.74	26.62	2.12	77.00	0.11	366.00
100% Rye flour	3.00	29.22	3.00	94.00	0.11	420.00
LSD	0.11	0.46	0.11	0.05	0.08	10.15

Physical properties of biscuits manufactured by different ratios of whole rye flour:

Data presented in Table (7) show that the specific volume was the only one physical prosperity, among all the other tested property, which was significantly high in the control biscuit than in each whole rye flour substitution samples. It was the result of the variation in grain physical properties. Such variation could be regarded to the grain(genus, variety, hybride) type and environmental conditions (Park *et al.*, 2000; Gökmen, 2004 and Soylu and Tekkanat 2007).

Table (7): Physical properties of biscuits manufactured by different ratios of whole rye flour

Biscuit samples	Specific volume (cm^3/g)	Volume (cm^3)	Weight (g)	Density (g/cm^3)
Wheat flour (72 %) Control	0.860	9.94	11.55	1.16
Wheat flour (72 %) + 25% Rye flour	0.733	10.00	13.64	1.36
Wheat flour (72 %) + 50% Rye flour	0.653	10.20	15.61	1.53
Wheat flour (72 %) + 75% Rye flour	0.654	10.22	15.62	1.52
100% Rye flour	0.659	10.27	15.59	1.51

Data presented in Table (8) show that showed that all the tested sample attributed were significantly differed than the control sample. It was, also, found that as the attribute values in case of 25% rye substitution sample was the highest and the 50% rye substitution sample was the closest one among all the other tested substitution ratios to such biscuit samples. On contrary, 75 and 100% rye substitution samples was the lowest preferred to the panelists with respect to the sensory evaluation attributes.

Table (8): Sensory evaluation of biscuits manufactured by different ratios of whole rye flour

Biscuit samples	General appearance	Color	Taste	Odor	Aftertaste	Crispness
Wheat flour (72 %) Control	9.35±0.18	9.31±0.14	8.65±0.40	8.86±0.40	8.97±0.40	8.92±0.38
Wheat flour (72 %) + 25% Rye flour	9.57±0.44	9.62±0.52	9.00±0.45	9.02±0.39	9.00±0.27	9.08±0.48
Wheat flour (72 %) + 50% Rye flour	9.00±0.49	9.34±0.44	8.45±0.15	8.78±0.20	8.93±0.65	8.58±0.14
Wheat flour (72 %) + 75% Rye flour	8.88±0.58	8.97±0.44	8.25±0.36	8.27±0.19	8.63±0.46	8.37±0.21
100% Rye flour	8.73±0.38	8.75±0.38	8.00±0.25	8.00±0.27	7.25±0.33	8.00±0.37
LSD	0.52	0.53	0.48	0.42	0.63	0.45

Therefore, it is recommended, with respect to the nutritional and sensory evaluation points, to utilize whole rye flour in healthy biscuit preparation.

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إستخدام دقيق الحبوب الكاملة للراى فى تصنيع البسكويت

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ينصح بإستخدام منتجات الحبة الكاملة فى تجهيز الوجبات الصحية لكونها مصادر غنية للألياف الغذائية والمواد ذات النشاط المضاد للأكسدة. ولذلك فقد أجريت الدراسة الحالية لمقارنة تأثير الإستبدال الجزئى (بنسب ٢٥، ٥٠ ، ٧٥%) او الكلى (١٠٠%) لدقيق القمح بواسطة نفس النسب من دقيق الحبوب الكاملة للراى فى تصنيع بسكويت ذو درجة قبول محببة للمستهلكين. وقد تم مقارنة تلك النواتج مع البسكويت المصنع بدون إستخدام دقيق الراى (الكونترول) من حيث الخواص الكيماوية والتغذوية والحسية.

وقد أظهرت عينات البسكويت المصنعة المختبرة خصائص كيماوية وطبيعة وتغذوية وحسية أفضل من عينة الكونترول. حيث كانت أكثر ثراءاً من حيث محتواها من الألياف الغذائية والخام، البروتين، الرماد، مركبات β-glucan ، العناصر المعدنية. ولذلك، ينصح بإستبدال نسب حتى ٥٠ % من دقيق القمح بدقيق الحبوب الكاملة للراى فى تصنيع البسكويت لأنها كانت الأكثر قبولا من حيث الخواص الطبيعية والحسية التى إستخدت فى الدراسة.

الكلمات الدالة: دقيق الحبوب الكاملة للراى، الخواص الكيماوية والطبيعية والحسية، البسكويت.

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