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Research Article
Dough Behavior and Quality Characteristics of Novel Bread Fortified with Some Medicinal Herbs

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Abstract

Background and Objective: Prolonging the shelf life by decreasing microbial spoilage, in bread and other bakery products are the challenges faced by bread producers. These are the foremost reason for using industrial antioxidants, to prolong the shelf life. In this study use of medicinal plants and natural herbs in foods was observed as an alternative to replace industrial antioxidants. **Materials and Methods:** Medicinal herbs, namely sage, anise and caraway were added at different concentrations (0, 0.25, 0.5 and 1% based on flour weight) to develop a novel bread formulation that replaces synthetic antioxidants with naturally occurring antioxidants. The dynamic rheological properties of dough produced with and without added herbs were assessed using a rheometer. Physical properties such as weight, volume, texture, odor and crumb and crust color were measured. In addition, sensory evaluation of the bread products was conducted. **Results:** The results showed that bread with concentrations of 0.25 and 0.5% of anise and caraway had good rheological properties and sensory acceptance. Bread dough with sage added at concentrations of 0.25 and 0.5% showed low displacement recovery in the recovery phase and constant displacement within the measuring time with the displacement decreasing indefinitely with time at herb concentrationsof 1%. In addition, there were no differences observed in the sensory evaluation of the crumb color, texture and overall acceptability between the control and the bread with added herbs. However, there were significant differences in taste and odor between the control and the bread containing flour with herbs added at high concentrations (1%). **Conclusion:** In general, the herbs in concentrations ranging from 0.25-0.5% can be used to produce bread with effective antioxidant properties and a longer shelf life.

Key words: Herbs, dough rheological properties, bread quality, sensory evaluation, antioxidant properties

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Bread is one of the oldest and most popular foods in the world. It is one of the main sources of carbohydrates needed by the body. Bread consists of essential ingredients, such as flour, water, salt and yeast and other minor ingredients such as industrial antioxidants, fat and sugar. The ingredients in bread play a vital role in influencing human health as bread is considered as one of the staple foods. Recently, there has been a significant increase in consumers' health awareness, leading to bakers fortifying bread with functional ingredients, such as dietary fiber and phenolic compounds to improve human health[1]. The search for natural and healthy alternatives to reduce calorie intake and increase the health benefits of foods is also necessary to reduce lifestyle diseases[2]. However, additional added ingredients should not affect the rheological properties, fermentation and baking time of the dough. In addition, sensory properties, such as flavor and odor and physical properties including crust and crumb color, texture and volume are expected to be maintained at an acceptable level.

Some of the challenges faced by bread producers include prolonging the shelf life by reducing rancidity and decreasing microbial spoilage, as these changes lead to the spoilage of bread and other bakery products. These challenges are the foremost reason for using industrial antioxidants and chemical preservatives, such as mold inhibitors, to prolong the shelf life. Since bread is one of the most important and prevalent foods consumed worldwide, it can be used as a functional food to effectively increase the intake of herbs that promote human health and prevent disease[2].

Due to the harmful side effects of industrial antioxidants and preservatives, many studies have been conducted to find natural sources of antioxidants, such as polyphenols and flavonoids. Alqahtani *et al.*[3] evaluated the feasibility of using tomato pomace powder, a by-product of processing tomatoes as a source of natural antioxidants in yogurt.

The use of medicinal plants and natural herbs in foods under the "back to nature" trend is being viewed as an alternative to replace industrial compounds[4]. Medicinal herbs are cheap, locally available, safe for health and have been consumed for thousands of years in food. In addition, they are used in many medical preparations to treat and prevent diseases as they contain beneficial phytochemicals. Herbs are also used in the food industry as natural antioxidants to protect fats from oxidationand improve the quality and nutritional value of food and are used as flavor compounds in many beverages[5,6]. Moreover, herbs are used in the field of dyeing, perfumes and cosmetics[7].

Therefore, this research aimed to study the effect of the medicinal herbs sage, anise and caraway at different concentrations (0, 0.25, 0.5 and 1%) on the dough rheology and sensory properties of bread formulated as a novel food high in antioxidants.

MATERIALS AND METHODS

Study area: The study was carried out in (Berlin, Germany) and (Hofuf, Kingdom of Saudi Arabia) from May, 2014 to November, 2016.

Specimen collection: Anise (*Pimpinella anisum*), caraway (*Carum carvi* L.) and sage (*Salvia officinalis*) were obtained from the Ministry of Agriculture, Giza, Egypt. Wheat flour (72% extraction) and other ingredients were purchase from a local market in Cairo, Egypt.

Dough preparation: The herbs (sage, anise and caraway) were added to wheat flour containing different concentrations of herbs added at 0, 0.25, 0.5 and 1%.

Evaluation of dough properties

Small deformation rheology: The dynamic rheological properties of the wheat flour dough were determined by the creep test using a rheometer UDS 200, UK[8].

Manufacturing the bread: The bread dough was prepared according to the International Association for Cereal Chemistry method[9]as follows:

- Five hundred gram flour (wheat flour or wheat flour fortified with 0.25, 0.5 and 1% of the different herbs)
- 1% sugar
- 1.2% salt
- 3% fresh compressed yeast
- 62% water

The baking process was conducted according to the method of Ghoshal *et al.*[10].

Bread characteristics: Weight, volume and specific volume of the final bread mass were measured after cooling for 3 hrs at room temperature according to the method of the American Association of Cereal Chemists[11]. The specific volume was obtained by dividing the volume of loaves by their weights. The color (crumb and crust) was also measured after 3 hrs of cooling.

Sensory evaluation: The bread was cooled for 2 hrs at room temperature before sensory evaluation. Panelists comprised of students and faculty members of the Department of Food Science and Nutrition at the Faculty of Agricultural Sciences and Food, King Faisal University, Egypt. Measurements, which include appearance, crumb texture, crust and crumb color, taste, odor and overall acceptability made use of a scale from one to ten with one being highly unsatisfactory and ten being excellent.

Statistical analysis: SPSS version 16 was used to analyzethe data collected. The variance between all treatments and Duncan's preference test[12] were performed to differentiate between the treatments. The mean ± the standard deviation of three replicate samples were used.

RESULTS AND DISCUSSION

Creep tests for wheat flour dough: The creep test is a dynamic rheological test, which aims to study the behavior of wheat flour dough, was used to compare the rheology ofthe test doughs under the same conditions. This method is distinguished from traditional methods of measuring the behavior and viscoelastic properties of dough as it does not reach the stage of destroying the dough. It also provides a clear picture of the internal structure of the dough. The maximum creep strain value, as strain at the end of the creep phase, was used to describe dough rigidity (firmness)[13].

Stronger dough with greater resistance to deformation has smaller creep strain than softer dough. Figure 1a-c shows the results of the creep test of the wheat dough control and the dough containing flour with the different concentrations of anise, sage and caraway (0, 0.25, 0.5 and 1%) respectively and depicts the ability of the dough samples to restore to its original shape.According to the results presented in this fig, wheat flour dough with different concentration of herbs leads to an increase in dough weakness with high concentration, which leads to a decrease in the creep curve over the time, as the dough is not able to resist the deformation and exhibit lowest resistance to deformation compared to control. So, the creep test revealed essential information related to the fundamental impact of studied herbs inclusion in bread dough.

Figure 1a-b, wheat flour dough with different concentration of Anise or Caraway at 0.25% addition level exhibit high resistance to deformation as it is shown by the increase of maximum creep compliance, compared to those contain 0.5 and 1%, showing smaller creep strain, as close as possible to control.

There was considerable variation in the creep behavior between the other composite flours with the added herbs.

The composite flour with sage concentrations of 0.25 and 0.5% exhibited low-recoverable displacement in the recovery phase that was constant within the measuring time; this displacement decreased indefinitely with time at a concentration of flour containing 1% herbs. This may be due to highly phenolic compounds in sage, mainly rosmarinic acid[14].

Figure 1a-c shows that there was no appreciable difference in the creep characteristics of the three flour doughs containing flour with herbs at concentration 0.5 and 1%. Increasing the level of herbs, which act as reducing agents[15], considerably reduced the resistance of the dough to extension and the dough extensibility increased. Thus, the incorporation of herbs decreased the strength of the dough.

There is an inverse relationship between the addition of flour containing herbs to the dough and the strength of the dough at a concentration of 1%. The findings showed that the higher the concentration of herbs, the less able the dough was to recover its shape and the degree of deformation was lower. This is proposed to be due to the increased number of disulfuric bonds and thiol groups[15].

The effect of medicinal herbs on the dough rheological properties may also be due to a change in the structure of the secondary and tertiary gluten proteins by the free radicals of phenolic acid[16], which breaks down the disulfide and non-covalent (ion or hydrogen) bonds, reducing the molecular weight of gluten and weakening the dough[17]. The mixing and stability time of the dough is also affected by the addition of phenol compounds for the same reason, namely the replacement of di-sulfuric bonds with thiol groups[18]. The results of this study are consistent with those of Dhillon *et al.*[19] who found decreased elasticity and viscosity of the dough supplemented with herbs like oregano and thyme. The results also show that the dough retained its ability to form, especially at lower concentrations of added herbs.

Influence of herbs incorporation on dough and bread properties: The rheological properties of dough are good indicators of its mixing, sheeting and baking performances. Dough expansion and bread texture depend on dough rheological characteristics, primarily due to the gluten and starch components. Phenolic compounds added to dough interact with the gluten's free radicals during mixing, thereby breakdown the hydrogenic and sulfuric bonds in bread dough[20].

Although the addition of the sage, anise and caraway at 0.25 and 0.5% to the flour led to a slight change in the texture of the dough, handling was still easy. As the concentration of

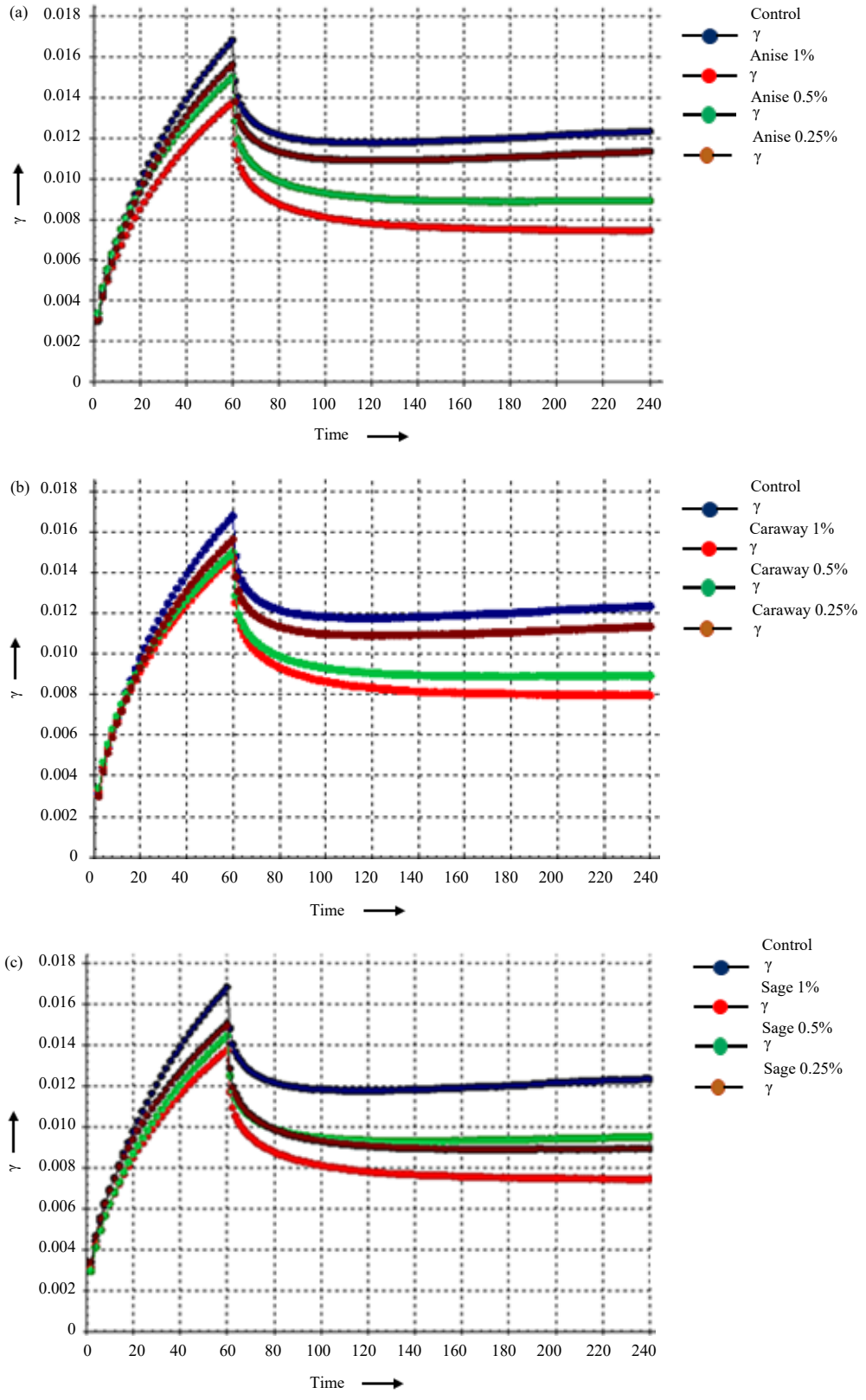

Fig. 1(a-c): Characterization of the creep curves of wheat flour dough mixed with different concentrations of (a) Anise, (b) Caraway and (c) Sage

Fig. 2(a-c): Dough properties of the wheat flour dough samples: Control and added herbs (a) Anise, (b) Caraway and (c) Sage

Table 1: Loaf characteristics of wheat flour bread: Control and added herbs

Herbs (%)		Height (cm)	Weight (g)	Volume (cm^3)	Sp. volume ($cm^3\ g^{-1}$)
Control	0	9.90^{bc}	369^{cd}	862^{ab}	2.34^{abc}
Anise	0.25	10.83^{a}	373^{bc}	887^{a}	2.38^{a}
	0.5	10.47^{ab}	372^{bc}	867^{ab}	2.33^{ab}
	1	9.63^{c}	373^{bc}	778^{d}	2.08^{d}
Caraway	0.25	10.80^{a}	377^{ab}	883^{a}	2.34^{ab}
	0.5	10.57^{ab}	377^{ab}	847^{b}	2.24^{abc}
	1	10.30^{ab}	382^{a}	787^{d}	2.06^{d}
Sage	0.25	10.80^{a}	365^{d}	862^{ab}	2.36^{a}
	0.5	10.13^{b}	369^{cd}	835^{c}	2.26^{abc}
	1	9.83^{bc}	368^{cd}	762^{e}	2.07^{ab}

Mean values in the same column show with the same superscript small letter are not significantly different ($p \leq 0.05$)

herbs in the flour increased to 1% handling became more difficult. Figure 2a-c shows that by increasing the concentration of herbs from 0.5-1% the texture was influenced, more especially with sage (Fig. 2c).

The weakening of the dough containing herbs may be explained by the effect of reduction gluten bonds by the phenolic compounds in herbs that decreases the elasticity and viscosity of the dough, which is reflected in its texture and handling. As a result, the volume of the bread containing herbs gradually decreases as the concentration of herbs increases as shown in Table 1. The results show that the volume of the wheat flour dough bread was considerably higher than the bread supplemented with herbs. Bread produced using herb concentrations of 0.25% was most like

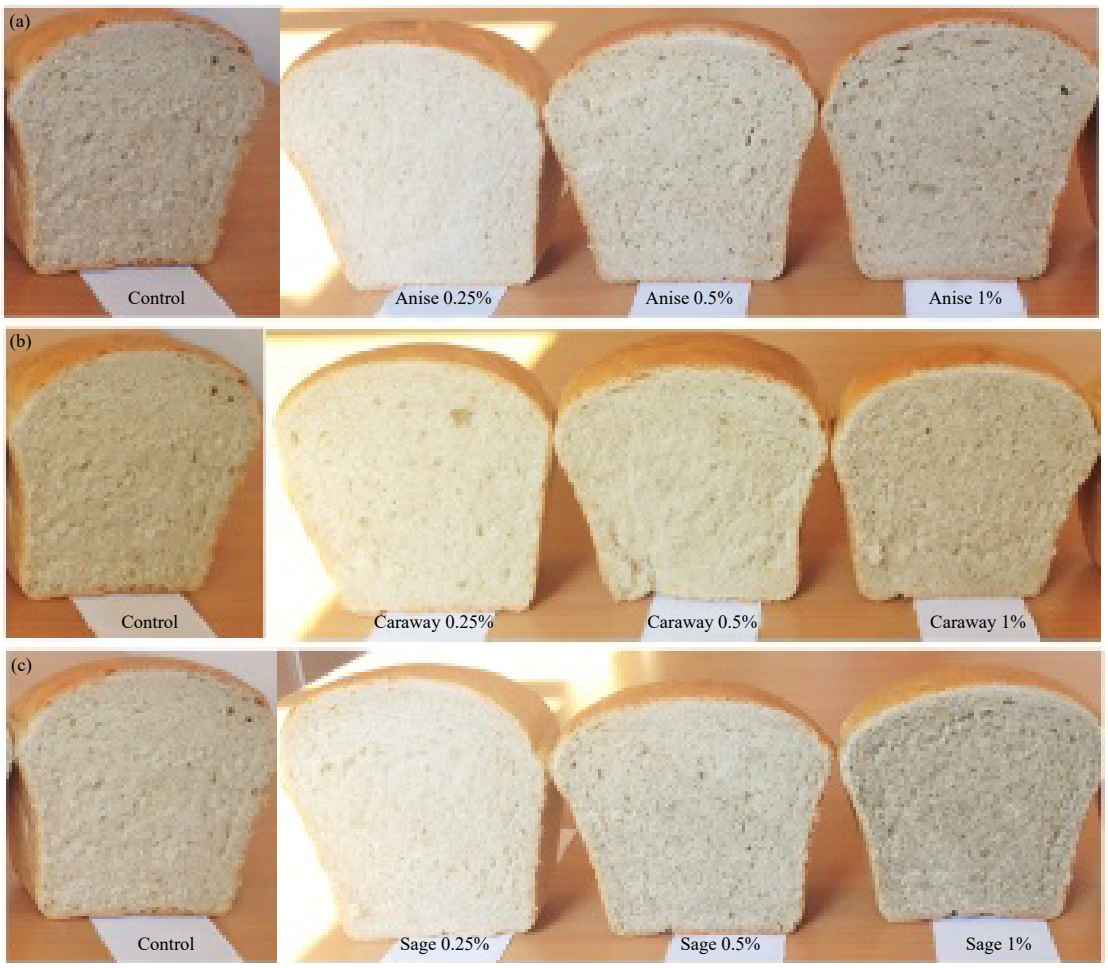

Fig. 3(a-c): Baking properties of wheat flour bread samples: Control and added herbs, (a) Anise, (b) Caraway and (c) Sage

the control bread, followed by the doughs containing composite flour with herb concentrations of 0.5 and 1%, respectively. These results were consistent with those reported by Xu *et al.*[18].

Several studies have confirmed that the addition of phenolic compounds to dough has a substantial effect on the properties of bread. It has been observed that ferric acid[21,22] and caffeine[17,20] result in a decrease in the volume and sticky texture of the bread.

Figure 3a-c shows the effect of adding the sage, anise and caraway on the characteristics of bread. The control sample shows a better crumb texture than the samples containing composite flour with herbs at higher concentrations (1%), which may be due to the formation of a stronger gluten network[23]. The addition of the herbs noticeably changes the hardness and strength of the crumb structure. This is due to the association of phenolic compounds with wheat gluten resulting in weaker cell walls being formed and a rough crumb structure. Bread made with flour containing herbs at a concentration of 0.25% was closest to the control bread. This was followed by samples containing flour with 0.5% herbs; the samples containing flour with 1% of herbs were affected the most.

Color measurements are represented in Table 2 showing the values obtained by a colorimeter that reflects the brightness (L), redness (a) and yellowness (b).

The crust color measurements of bread containing 0.25% of each Anise (60.52, 9.62 and 33.54) and Caraway (57.91, 9.45 and 30.61) were closest to the control (57.68, 10.11 and 31.44) for L, a and b values respectively. While at the same concentration (0.25%) of sage resulted a little difference in color measurements L, a and b (55.72, 9.76 and 29.64 respectively) with the control. The darkening (L value) observed in the bread crust (49.07, 54.42 and 54.79) or crumb (61.06, 67.94 and 67.22) containing more than 0.5% herbs for Sage, Anise and Caraway respectively compared with control (57.68 and 71.32 for crust and crumb respectively). It was found that an increased concentration of herbs resulted in a

Table 2: Color measurements of wheat flour bread: Control and added herbs

Samples	Concentration herbs (%)	Crust color			Crumb color		
		L	a	b	L	a	b
Control	0	57.68^{abc}	10.11^{a}	31.44^{bc}	71.32^{a}	-0.85^{de}	17.50^{b}
Anise	0.25	60.52^{a}	9.62^{ab}	33.54^{a}	71.34^{a}	-0.65^{bcd}	17.84^{ab}
	0.5	57.65^{abc}	10.18^{a}	31.77^{bc}	69.56^{abc}	-0.66^{bcd}	17.57^{b}
	1	54.42^{c}	10.04^{a}	28.92^{d}	67.94^{bc}	-0.58^{bc}	17.87^{ab}
Caraway	0.25	57.91^{ab}	9.45^{ab}	30.61^{cd}	70.22^{ab}	-0.97^{e}	17.90^{ab}
	0.5	55.24^{bc}	9.64^{ab}	29.45^{d}	70.19^{ab}	-0.79^{cde}	17.47^{b}
	1	54.79^{c}	8.52^{b}	32.74^{ab}	67.22^{c}	-0.29^{a}	18.43^{a}
Sage	0.25	55.72^{bc}	9.76^{ab}	29.64^{d}	67.33^{c}	-0.86^{de}	16.28^{c}
	0.5	55.64^{bc}	9.03^{ab}	29.65^{d}	63.96^{d}	-0.74^{cd}	15.67^{c}
	1	49.07^{d}	9.59^{ab}	24.79^{e}	61.06^{a}	-0.50^{b}	15.67^{c}

Mean values in the same column show with the same superscript small letter are not significantly different ($p \leq 0.05$), L: Brightness, a: Redness and b: Yellowness

Table 3: Sensory evaluation of wheat flour bread: Control and added herbs

Herbs (%)		Appearance (10)	Crust color (10)	Crumb color (10)	Crumb texture (10)	Taste (10)	Odor (10)	Overall acceptability (10)
Control	0	9.42^{a}	9.57^{a}	9.71^{a}	9.57^{a}	9.43^{a}	8.86^{ab}	9.29^{a}
Anise	0.25	7.86^{abc}	8.00^{ab}	8.71^{ab}	9.14^{ab}	8.29^{ab}	9.00^{a}	8.43^{ab}
	0.5	7.57^{bc}	7.86^{ab}	8.42^{ab}	8.71^{ab}	7.29^{bc}	8.29^{ab}	7.43^{c}
	1	5.71^{d}	7.57^{b}	7.43^{bc}	8.28^{ab}	7.00^{bcd}	6.71^{b}	6.29^{d}
Caraway	0.25	7.86^{abc}	8.57^{ab}	9.00^{ab}	7.86^{c}	8.29^{ab}	8.71^{ab}	8.44^{ab}
	0.5	6.86^{c}	7.28^{b}	8.71^{ab}	7.28^{bc}	7.00^{bcd}	6.57^{c}	7.43^{bc}
	1	7.28^{bc}	6.86^{b}	8.42^{ab}	5.57^{c}	6.71^{cd}	5.86^{cd}	7.17^{bc}
Saga	0.25	8.71^{ab}	8.71^{ab}	8.43^{bc}	7.57^{bc}	7.86^{cd}	7.29^{bc}	8.42^{ab}
	0.5	8.14^{abc}	8.28^{ab}	6.57^{cd}	6.14^{c}	6.42^{cd}	6.00^{c}	6.14^{d}
	1	7.42^{bc}	7.71^{ab}	5.57^{d}	6.14^{c}	5.71^{d}	5.14^{cd}	5.29^{e}

Mean values in the same column show with the same superscript small letter are not significantly different ($p \leq 0.05$)

darker crust color than the control bread containing no herbs, may be attributed to an increased in the Maillard reaction during baking due to a higher lysine content. In the Maillard reaction reducing carbohydrates react with free amino acid side chains of protein, mainly lysine and lead to amino acid-sugar reaction products (polymerized protein and brown pigments)[24]. This reaction may compromise the nutritional value of foods through the destruction of essential amino nutrients[25]. For the crumb color, as the herb concentration was increased higher values of a and b were obtained indicating more redness and yellowness in the crumb color, which can be attributed to the addition of the herbs. Changes in the color of the bread containing 1% of different herbs may be due to the high concentrations of phenolic compounds that increases the velocity of the Maillard reaction[26].

Table 3 shows the results of the sensory evaluation and indicates that the bread samples supplemented with sage, anise and caraway at 0.25% concentrations in the flour were very attractive to most people, especially in terms of texture, taste and color depends on the panel test. This is followed by the samples produced using flour with a concentration of 0.5% added herbs. In bread containing flour with 1.0% added herbs, there was a reduction in all the measured values (crust and crumb color, crumb texture, taste and odor) and the overall acceptability of the bread. In general, bread supplemented with herbs with up to 0.5% herbs added to the flour show good sensory acceptance in comparison to the control containing no herbs in terms of weight, volume and crumb and crust color. These results indicate the possibility of using the herbs tested in the baking industry to increase antioxidant content with the added benefit of improved human health[27].

CONCLUSION

The purpose of this study was to investigate the effect of the addition of herbs, including sage, anise and caraway, at different concentrations (0.25, 0.5 and 1%) on the dynamic rheological properties of wheat flour dough and bread characteristics. The results of the creep test show that the rheological properties of the dough were not affected at low concentrations of composite flour containing herbs at 0.25 and 0.5%, with the most pronounced effects being observed for sage. However, at concentrations of 1% of added herbs, the dough became more difficult to mix and form. The volume and sensory characteristics of the bread containing flour with herb concentrations of 0.25% closely resembled that of the control, followed by the bread made with flour containing 0.5% of the different herbs. The results indicate that sage, anise and caraway could be successfully utilized as a natural source of antioxidants in the bakery industry and to produce healthy baked products.

SIGNIFICANCE STATEMENT

This study shows that it is possible to develop novel bread containing natural ingredients like herbs for its health attributes. The antioxidant and antimicrobial components present in herbs could enable them to enhance the health of human being and long shelf life of resulting bread. Combination of herbs in bakery products with gifted health benefit should conform to avoid any side effects with respect to dough quality, testing and sensory evaluation of final bread. However, there are numerous technological challenges that have to be carried out to develop bakery products enriched with herbs like using dynamic rheology to predict the dough characteristics. This study will help the researchers to uncover the effects of the addition of herbs on the dynamic rheological properties (creep test) of wheat flour dough that many researchers were not able to explore.

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