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RESEARCH ARTICLE

Effects of Ivory Coast's Plantains Peel Potash on the Rheological Properties of Wheat Flour Dough Bread

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Abstract

The objective of this work was to study the effects of artisanal potash produced in Ivory Coast on wheat dough and the final bread rheological and physical properties. Glucose oxidase was addedto improve dough's viscoelasticity. This potash was manufactured and used replacing the kitchen salt in breadmaking.Doughs consistency, resistance, strength, extensibility to deformation and gas bubbles development were determined at kneading and fermentation processes. Breads physical properties were then observed and crumbs resistances to deformation were performed.The obtained potash were in the form of light grey pebbles and tastes salty. The final bread's rising volume, density, strength and extensibility to deformation were obtained depending on initial dough viscoelasticity. The bread dough containing potash is less extensible to deformation than the dough with salt in a ratio of 1.38±0.03%.The breads crumb enriched by glucose oxidase are more resistant to deformation. However, the resistance to deformation of bread crumb enriched with potash is higher than that of the bread with salt by a ratio of 1.02±0.07%. The crumb of the bread with potash is more elastic and homogeneous appearance alveoli. Its crust is thinner and slightly darkened. This bread with potash is airy and tender for consumers.Potash can be used in bakery in substitution of kitchen salt. It is usedin small quantity and therefore probably less carcinogenic for long term using.

Keywords: *Wheat flour dough bread; potash; plantains peel; rheological properties.*

Introduction

Bread is one of the oldest and popular foods of mankind. This bakery product is a good source of calories because of its abundant starch [1, 2]. It's obtained mainly from wheat flour, water, yeast and salt [3].Bread is a bakery product preferred by consumers for its firmness and freshness which indicate its apparent quality. These physical properties are essential for bakery process because of the main ingredients component. Indeed, wheat flour contains gluten, a protein which determines the dough viscoelasticity behaviour [4, 5]. This protein is water compatible and thus, swells and interacts together with other proteins of wheat flour. Gluten protein has key role in determining the only baking quality of wheat by conferring water absorption capacity, cohesivity, viscosity and elasticity on dough [6]. The yeast has mainly a fermentation role but added to salt, they contribute to the final bread flavour [7]. According to Burnier et al. [8], salt gives savour and hides undesirable aftertastes in food. Moreover, it plays a very significant technological role in transforming and preserving cereals, meats, fishand vegetables. In the breadmaking process, the sodium chloride has for main action to consolidate the glutinous network by creating ionic connections between water and gluten proteins [9]. It retains water and decreases the sticking properties of the dough, thus allowing a better kneading. During fermentation, it slows down the activity of the yeast in order to standardize alveoli creation and to make easier bread's preserving [10].

The usual cooking salt appears to be for a long time, irreplaceable in human diet and food processing. That is due to people usual food practices, functional abilities of food and thus the roles of sodium chloride in the cellular metabolism [11]. Thus, these qualities of salt make it very important and overlooked flavour enhancer. However, the link between an excessive salt consumption (over 10 g per day) and metabolic diseases, mainly hypertension, is a real fact [12]. Burnier et al [8] showed that apart from sensitizing and the risk factors monitoring measurements, other measures must be taken.

The aim of this work is to determine effects of traditional potash on wheat bread in order to substitute it to the usual cooking salt (NaCl) in breadmaking process. The interest of this approach is to help to some industrial and agricultural refuses valuation, to increase producer's incomes producing their own salts and then ensure consumer's food safety by bringing a less aggressive salty product. Some investigations have permitted to make a census of edible salts from vegetable, most eaten and available of Ivory Coast in order to establish their manufacturing diagram. The artisanal potash methods of production, raw material, functional and physicochemical properties in bakery are discussed.

Materials and Methods

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Ingredients for Bread Dough

All-purpose wheat flour (type 55) variety "Apache" obtained from Boromir Group (Romania) was used without any chemical or proteins supplementation. It contained 12.3 wt % water, 11.6 wt % protein and 0.58 wt % ash (moist basis) being particularly intended for baking products. It was stored in a freezer at −20°C for 7 days and then at 4°C for 1 to 3 days before using.

Basic dough formula (on flour basis) consisted of 2.0 wt % salt or 0.075 wt % potash, 1.62 wt % glucose, 51.96 wt % water (added water), 5 nkatal/g of glucose oxidase (GOX) (only for dough with GOX, GOX could be used 48 hours after preparation) and 3 wt % yeast (used up to 96 hours after preparation and only for dough fermentation). The ingredients were weighed and placed in sealed boxes in a refrigerator at 4°C during the night before the test. Four formula doughs were used: bread dough containing salt (BS), bread dough containing potash (BP), bread dough containing salt and GOX (BSG) and bread dough containing potash and GOX (BPG).

Plantain Peels Potash

The plantain peels potash manufacturing consisted of peeling the ripe plantains andthen drying the peels at the sun for 7 days. The sun-dries peels have been incinerated at 550°C for 12 hours [13]. Water was added to the ash and leached to obtain mixture alkaline water. This mixture is heated at 105°C for 24 hours to obtain wet potash. It is then dried at the sun for 12 hours to obtain the final potash (Figure 1)

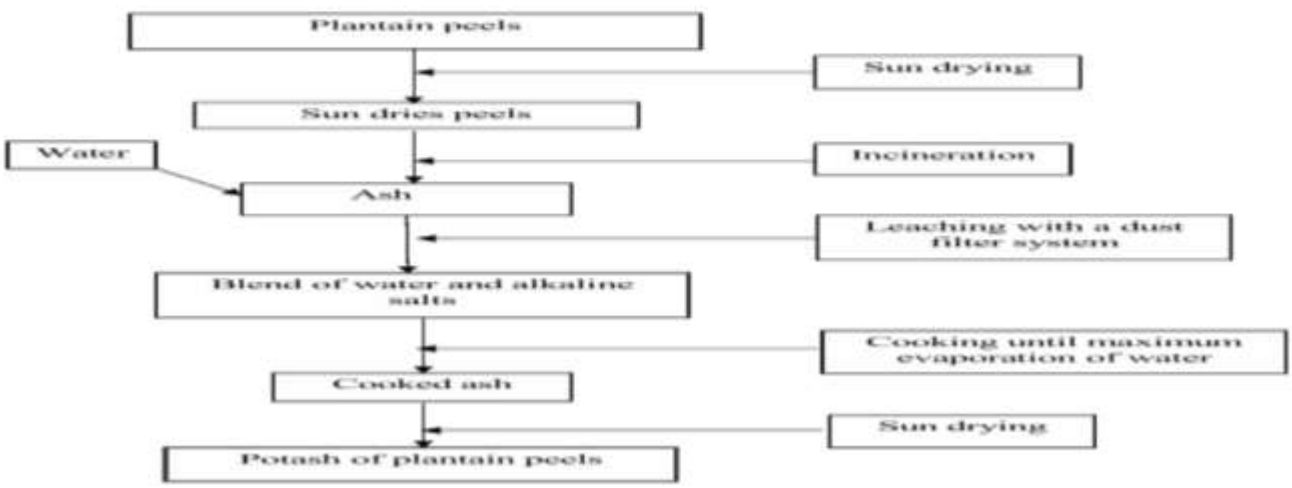

Figure1: Traditional plantain peels potash manufacturing diagram

Sample Dough Mixing Ingredients, Kneading and Manufacturing

The Bra bender Farinograph (Bra bender-USA) was used to mix ingredients and to knead the dough. It has a capacity of 300 g flour (450-500 g dough). For the kneading process, 200g of wheat flour have been used. The Bra bender in dictated maximum water absorption capacity and 85% of humidity (ambient conditions). The water temperature was 4±0.2°C in order to have correlation with the water recirculated temperature in the Farinograph system. The kneading time was 5.8 minutes necessary to obtain bread dough with a high quality [14]. Paraffin oil (η = 0.15 Pa. s) was used as a lubricant before mixing ingredients. It satisfied the conditions of Secor et al. [15] and Macosko [16] considering wheat flour dough viscous properties.

Dough at 41.3 wt % water (total water moist basis) was obtained at the end of the kneading process. It was then left to rest for 5 min at 25°C tightly closed in the storage system of Chopin Alveograph to allow the relaxation of induced stresses during kneading process before compressions tests [17]. The manual laminating system of the Chopin Alveograph [18] was used under lubricated conditions to prepare samples of thicknesses L_0 = 08 ± 0.15 mm by manual rolling (8 round trips). A disk was then cut with a circular punch (diameter 32 mm) to obtain samples for rheological tests with an initial aspect ratio $2R0/L0$ of 4 [19]. Paraffin oil (η = 0.15 Pa.s) was used as a lubricant. The conditions described by Secor et al. [15] and Macosko [16] were satisfy considering wheat flour dough viscoelastic properties.

Fermentation Products

Moulding dough

After kneading, 250 g of dough were removed, shaped manually into a cylindrical sample and placed in a Pyrex mould (140 mm of diameter and 70 mm of thickness). The hands were first cleaned with a sample of the same flour used for kneading in order to minimize the dough stickiness on the palms and skin during the shaping. The bottom of the moulded dough's were covered with greaseproof paper and the edges were lubricated with a thin layer of rapeseed oil (η = 0.16 Pa .s was used as a lubricant as describedbySecor et al. [15] and Macosko [16] for the restoration of the full sample dough. The sample was tightly closed with plastic cover.

Fermentation dough

The moulded doughs were placed in a fermentation oven regulated at 25 °C. Cylindrical tank glass graduated at 1 to 7 cm ensured the bread dough fermentation level control. A cylindrical dough sample of 25 ± 0.5g was placed in the mould tank. The mouldeddoughs werefermented for90 min. This time (90 min) was essential to obtain better fermented dough than those made with a standard 180 min of fermentation [20]. A disc was placed above the sample dough slides during the fermentation. It served as an indicator for the bread dough rising. Measurements data were taken every 10 min. The volume of the rising dough during fermentation was evaluated considering its initial and reached level at the time t (min) by the formula:

$$V_{pi} = \pi R^2 L \qquad (1)$$

V_{pi} is the dough volume at the time t (min); R, the radius of themeasuring cylindricaltank; L, the dough thickness at the time t (min) and π=3.14, a constant.
Considering that the deformation of the sample dough during the fermentation is uniaxial and its development surface is perfectly horizontal, the deformation is defined by Hencky [21] that:

$$\varepsilon_u = -in\ (L_0/L) \qquad (2)$$

ε_u is the uniaxial deformation; L_0 is the initial thickness of the sample dough and L, the thickness at time t.

The sample dough was cylindrical, so the thickness ratio was equal to the ratio of its volumes at time t (min). The deformation of Hencky [21] is then given by:

$$\varepsilon_u = -\ln\ (V_0/V) \qquad (3)$$

V_0 is the initial volume of the sample dough and V, the volume at time t.
In this case, the deformation was followed versus time during the fermentation.

Baking Dough

The fermented dough was baked in domestic oven (Henry Simon Limited, Cheshire, UK) during 60 min at 180°C of temperature. The beginning and the end of the process were indicated by a beep sound emitted by the oven temperature regulator system.

Bread Texture Analysis

Bread freshness and hardness propertieswere determined by CT3 Texture Analyzer (10 kg load cell) using Texture Pro CTV1.5 Software (Brookfield Engineering Laboratories, Inc. USA) for equipment control and initial data handling. A cylinder probe TA4/1000 of 38.1mm diameter was attached to a moving cross-head.

A stainless-steel knife was used to prepare cylindrical slices bread 25 mm of diameter and 52 mm of thickness. Sample bread was then centred under probe. It was compressed under the following conditions: 1 $mm.s^{-1}$ of constant cross-head speed, 5g of trigger load and 70% of maximum deformation.

Bread Crumb and Crust Physical Properties

The bread crust and crumb were directly observed visually considering the colour, touch feeling, crust thickness and crumb alveoli width and number.

Samples slices bread were cut in the parallel direction of it's lifting into the oven during the baking process in order to preserve and protect their alveolar structure. Samples breads 3 mm of thickness were scanned. Picture was takenwith aflatbed scanner (Epson® Perfection V370 Photo Flatbed Scanner) covered with ablack boxto avoid the influenceof the surrounding light. This device providedgoodcontrast betweenthe black backgroundand the clearbrackets. The slices breads were positioned in the centre of the scanner to minimize the variations of resolution during imaging. The images were taken with 4800 x 9600 dpi optical resolution and enlargement up to 13" x 19". These samples were eventually observed visually from (x100) of image scale magnitude. They showed slices crumbs alveolar width and crusts thickness. Slices crumbs and crusts were visualized 24 hours after the baking process to have total firmness and freshness concentrations.

Statistical Analysis

All experiments of this study were performed in triplicate to calculate mean values and standard deviations. Data were explored using analysis of variance (ANOVA) and correlations. Tukey's honest significant difference (HSD) test at $P < 0.05$ was used for mean values separation. A significant result was indicated when the significance of the ANOVA associated with the regression analysis was less than 0.05. The relationship between measured parameters was also assessed by Pearson's test (significant level at $P \leq 0.05$).

Results and Discussion

Artisanal Potash

The study consisted to substitute salt for artisanal potash, produced in Ivory Coast, in bread making process. Artisanal potash manufacturing was performed in accordance with a traditional diagram that has been improved. The obtained potash is in the form of light grey pebbles and tastes salty (figure 2). This potash, made from plantain peels, is a salty and edible product consumed for a long time by several people, notably Western Africa's people [22]. Its manufacturing, doesn't utilize any chemicals and additives products. Thus, it won't be considered as naturalness than the usual kitchen salt, like potassium chloride (KCl) [10].

Figure 2: Artisanal potash

Dough Gas Bubbles Volume Rising during Fermentation

The physical properties of dough in breadmaking process include resistance to deformation, extensibility, elasticity and stickiness properties [23]. However most of the desirable changes are related to the ability of the dough to retain gas bubbles. Also, the uniform expansion of the dough piece under the influence of carbon dioxide gas from yeast fermentation during proof and baking processes were also permitted by these changes [24].

In order to ensure the quality of bread after baking, a study of gas bubbles development during fermentation appears necessary to assimilate dough behaviour during baking process. To ensure this case, the measurement of gaseous volume or pressure produced during dough fermentation was used to evaluate the effects of some ingredients in the formulation of bread dough during the maturation process.

Fig. 3 shows the variations between four bread dough formulas (BS, BP, BSG and BPG) volume versus time during their fermentation. Breads doughs volumes increased slowly during the first 10 minutes. Acceleration of the dough volume is observed versus time to reach a maximum after 90 minutes. The bread dough containing potash is less extensible to deformation than the bread crumb with salt in a ratio of 1.38±0.03%. A ratio of 1.22±0.04% of gas bubbles development is observed between BSG and BS. This result confirms those of Kouassi-Koffi et al [23]. This volume of dough depends on CO_2 variations. The volume of CO_2 of the dough enriched by GOX was significantly higher than the dough without GOX due probably to the GOX catalytic activities. Haarasilta et al [25] indicated that the catalytic activities of glucose oxidase lead to the gas bubbles rising. They show that the GOX supplementation to the dough modified the gluten proteins (gliadins and glutenins) reactions activities. GOX's action leads to the creation of disulfide and no disulfide crosslink's.

According to Vemulapalli et al. [26, 27], the basis of oxidation by GOX has been known to be a result of the hydrogen peroxide produced, which yields dough that is more elastic and viscous than the control without GOX. The dough becomes thus more elastic. Tilley et al and Rasiah et al. [28, 29] specified that this oxidation induces the formation of disulphide bonds by coupling of two cysteine residues. It results the covalent crosslinking of proteins which induces the formation of gas. But in this work, the volume of BPG at 90 min of fermentation is less high than the one of BP in a ratio of 1.22±0.02. Also, BPG's volume at the same time (90 min) is less than BSG's volume in a ratio of 2.09±0.09 (figure 3). Normally, the higher value of BPG dough fermentation volume should have been higher than that of BP, but it isn't the case because of potash addition. The catalytic action of the enzyme is probably inhibited by the artisanal potash because we observe a continuous increasing effect of the volume of the dough containing the cooking salt which must be discussed.

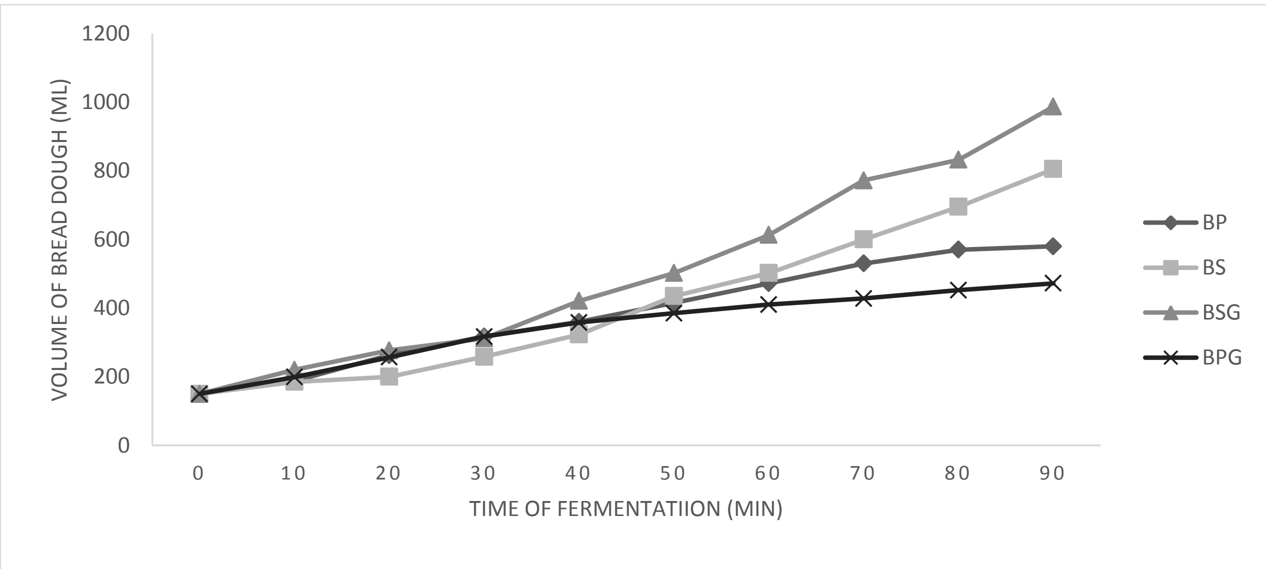

Figure 3: Variation of wheat bread dough volume versus time during fermentation process. Temperature = 25°c

Bread Texture

Peak resistance of the wheat bread crumb to deformation is defined as an indication of bread firmness and freshness. The bread firmness and freshness could be influenced by the dough viscoelasticity level and the formulation ingredients [23]. In order to know how bread dough quality could be influenced by the potash addition, the resistance and extensibility tests of bread to deformation were performed (Figure 4).

Fig. 4 shows the variations of wheat bread crumb compression force versus time. Bread crumb peak resistance to deformation, as shown by maximum height within curves, may be termed "crumb strength" and indicator of better quality of bread. The breads crumb enriched by GOX (BSG and BPG) are more resistance to deformation than the breads crumbs without GOX (BS and BP). These results confirm the increasing effects of the glucose oxidase addition to the bread dough [25]. However, the peak resistance of deformation of bread crumb with potash (BP) is higher than the one of the bread with salt (BS) by a ratio of 1.02±0.07%. These values are probably due to each dough formulation ingredients. The different doughs were consistent for baking products because their values were higher than 500 Bra bender Unit (BU) [30], the arbitrary unit value for dough consistency quality.

The distance between the trigger value and the peak resistance of the bread to deformation is measured in millimeter (mm) and termed "crumb extensibility" necessary for bread's freshness and firmness quality. At the end of compression test, was 0.235 min for the whole breads crumb, apart from the bread crumb of BP (0.325 min) (Figure 4). The extensibility time of BP (0.325) is higher than the three others (BS, BSG and BPG) extensibility time. This high value of BP crumb extensibility to deformation confirms the active action of the traditional potash.

The area between trigger point and peak resistance to deformation which may be termed "bread crumb work" is larger for the dough enriched by GOX (BSG and BPG) than the dough without (BS and BP). However, a ratio of 1.4±0.7% is perceived between BS and BSG and then between BP and BPG, it was observed a ratio of 0.6±0.2%. The effect of GOX in the bread containing salt is more perceptive (Figure 4) than the bread containing potash probably due to potash's inhibition action on the GOX. This behaviour of the breads crumbs approves their dough height elasticity and tenacity level related by Hibberd and Parker [31]. Similar results of these authors over a staling period have shown greatest and most significant difference between samples within bread crumb extensibility and area of work to peak deformation because of difference viscoelasticity level between bread crumbs. However, the peak values of crumb strength were shown to illustrate some inconsistency. They may thus affect significantly the tests data which were confirmed by Bloksma [32]. Also, the action of salt leads to strengthening of glutinous network. This action is due to the ionic links creates by the main ions (Na^+ and Cl^-) in salt (NaCl). Now, according to Martin and al [22], the main ionic component in potash is K^+. The observations obtained from slices crumbs (figure 4) show that the bread enriched by potash (BP) has good resistance, strength and extensibility than the bread with usual kitchen salt (BS). The roles of bread crumb viscoelasticity and consistency levels because of GOX and potash effects become important to be discussed.

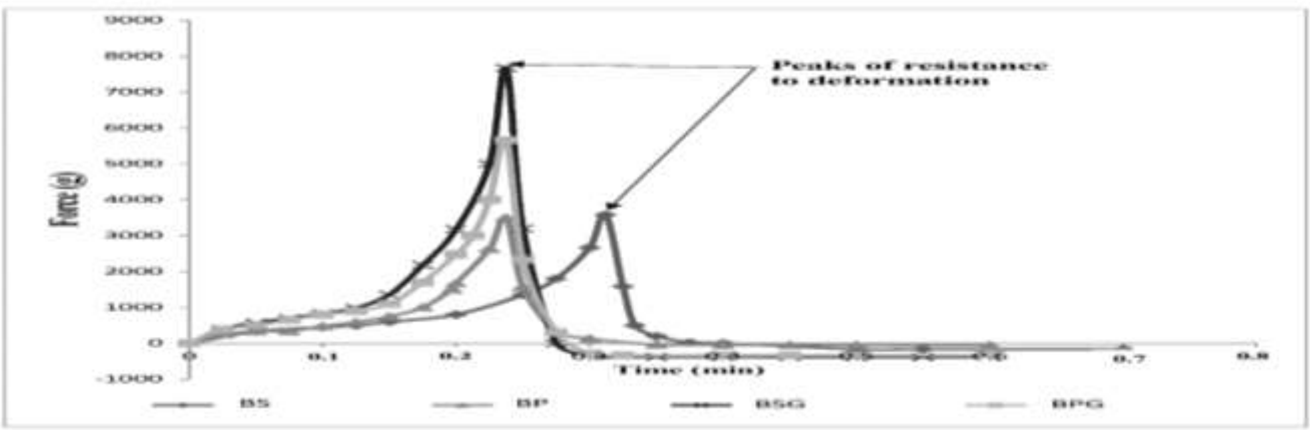

Figure 4: Variation of bread crumb compression Force versus Time – Bread crumb samples with and without GOX, temperature = 25°C.

BS = wheat dough containing salt; BP= wheat dough containing potash; BSG= wheat dough containing salt and GOx; BPG= wheat dough containing potash and G Ox; G Ox= glucose oxidase.

Bread Crumb Physical Properties

Physical properties of the bread are the first qualities criterions of consumers choices because they can be touched, observed and smelled directly. In order to know how the physical properties of the bread crumb can help to understand a basic structure improvement, visual characterization of sliced bread by images pickup was done. The alveolar structure of bread crumb is an important factor that contributes to the textural properties of fresh bread. Bread crumb alveoli width and their quantity can predict its aeration, porosity and compatible properties related by Bailey [33]. These characteristics of bread give indications of digestive quality.

Fig. 5 shows images of slices crumbs alveolar width and crusts thickness for samples breads. The crumbs of breads enriched by GOX (BSG and BPG) show more alveoli with larger and rounded diameters. The crusts have less thick and homogeneous appearance, but the crust of the BPG is less thick than the crust of the BSG (Figure 5a$_2$ and 5b$_2$). In contrast, the crumbs of the breads obtained without GOX shows few alveoli with smaller width and heterogeneous appearance. These crumbs are sparse and thick. The crusts are thicker and slightly darkened. They present more white dots which are not good quality marks (Figure 5a$_1$ and 5b$_1$). However, the crust of BP is less thick than the crust of BS probably due to potash effects during the baking process.

Higher is alveoli quantity and less is the thickness of the crust, better is the quality of the bread confirmed byHibberd and Parker [31]. These physical properties of bread are very important to staling evaluation and general crumb quality control [33]. They confirmed that measurement of bread crumb rheological properties is the evaluation of its staling, conservation and then its general quality control. Willhoft's [34] crumb rheology study devoted sections to measurements of the firmness, softness, compressibility and elasticity which are similar with our results. He has developed that rheological properties are necessary and as indicator of better quality of bread. These rheological properties of bread crumb obtained with GOX addition can now led to several methods developed in rheology and microscopy for bread crumb structure and texture studies.

A1- BS= Wheat bread with salt
A2- BSG= Wheat bread with salt and GOX
B1- BP= Wheat bread with potash
B2- BPG= Wheat bread with potash and GOX

Figure 5:Images of wheat bread crumb and crust alveolar physical appearance; a$_1$ and a$_2$ - bread crumb and crust with salt; b$_1$ and b$_2$ - bread crumb and crust with potash; GOX = glucose oxidase; (4800 x 9600 dpi) image optical resolution, (13" x 19") image enlargement. (x100) amplitudes of images scale, ( ) bread crust thickness level.

Conclusion

Bread rheological properties such as strength, consistence and extensibility are important for the milling and bakery industries in view of the prediction of dough processing parameters and the quality of final bread. Knowledge of the dough, enriched by potash rheological parameters, is permitted to obtain the wished bread. So, studying wheat bread, enriched with potash, rheological properties allow obtaining information on the possibilities of its using in substitution of the usual kitchen salt in bread making process. The Ivorian artisanal potash is a natural product in the form of light grey pebbles. This potash is generally made from plantain peels and other vegetable rests (palm and coconut branch, sugar cane, cocoa pod, coffee hull, cassava peel). It is a salty and edible product consumed for a long time by several people which must be valued in a view of these results. It gives in breadmaking process good bread because of its final crumb and crust interesting physical properties. The crumb is more elastic and homogeneous appearance alveoli. The crust is thinner and slightly darkened. The final bread is airy, tender for consumers. Potash can be used in bakery in substitution of kitchen salt. It is usedin small quantity and therefore probably less carcinogenic for long term using.

Acknowledgments

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