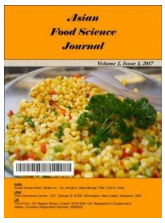

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Evaluation of Potassium Bromate in Bread in Ibadan Metropolis: Fifteen Years after Ban in Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author AIA designed the study, performed the statistical analysis, wrote the protocol and the draft of the manuscript. Authors EOO and UO managed the literature searches. Authors APA and APO managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

Background: In 2003, the National Agency for Food, Drug Administration and Control (NAFDAC), the agency responsible for regulating drugs, foods and chemicals in Nigeria, banned the use of potassium bromate in bread on account of its deleterious effect and carcinogenicity in humans.
Aim: This study is aimed at investigating the level of compliance to the use of potassium bromate in bread fifteen years after ban.
Study Design: This study was made to fit a one way Analysis of Variance.
Place and Duration of Study: This research was carried out in Ibadan, the Oyo State capital of Nigeria between July and December, 2018.
Methodology: Thirty loaves of bread were purchased in Ibadan metropolis. They were analyzed qualitatively and quantitatively for the presence of potassium bromate in them. Quantitative determination was done using spectrophotometric method that is based on the redox reaction between bromate and promethazine hydrochloride in an acidic medium. The absorbance of the

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product was read at 620 nm. The qualitative test was performed directly on a portion of each bread sample using 2 ml of 0.01 M promethazine and 0.6 ml of 12 M hydrochloric acid. The change in colour of each bread sample to purple indicates the presence of potassium bromate.
Results: All the 30 bread samples analyzed contain potassium bromate. The concentration of $KBrO_3$ in the sampled bread ranged between 1.24 µg/g and 9.31 µg/g. The quantity of $KBrO_3$ in each bread sample correlates with the degree of purple colour obtained in the qualitative test.
Conclusion: Since all the sampled bread had potassium bromate in concentration above safe level for human consumption, bread consumers and bakers are at risk of exposure to potassium bromate with health implications. The need for continuous surveillance and enforcement of the ban on use of potassium bromate in baking industry in Nigeria is recommended.

Keywords: Bread; carcinogenicity; Ibadan; NAFDAC; potassium bromate.

1. INTRODUCTION

Bread is a staple food prepared from dough of flour and water, usually by baking. Throughout recorded history it has been a prominent food in large parts of the world and is one of the oldest man-made foods, having been of significant importance since the dawn of agriculture. Bread may be leavened by processes such as reliance on naturally occurring sourdough microbes, chemicals, industrially produced yeast, or high-pressure aeration. Commercial bread commonly contains additives to improve flavor, texture, color, shelf life, nutrition, and ease of manufacturing. Bread plays essential roles in religious rituals and secular culture [1]. Bread can be served at many temperatures; once baked, it can subsequently be toasted. It is most commonly eaten with the hands, either by itself or as a carrier for other foods. Bread can be dipped into liquids such as gravy, olive oil, or soup; it can be topped with various sweet and savory spreads, or used to make sandwiches containing meats, cheeses, vegetables, and condiments. Bread is used as an ingredient in other culinary preparations, such as the use of breadcrumbs to provide crunchy crusts or thicken sauces, sweet or savoury bread pudding, or as a binding agent in sausages and other ground meat products [1].

Nutritionally, bread is categorized as a source of grains in the food pyramid and is a good source of carbohydrate and nutrients such as magnesium, iron, selenium, B vitamins, and dietary fiber [2]. Bread crust is formed from surface dough during the cooking process. It is hardened and browned through the Maillard reaction using the sugars and amino acids and the intense heat at the bread surface. The crust of most breads is harder, and more complexly and intensely flavored, than the rest [3]. Old wives tales suggest that eating the bread crust makes a person's hair curlier. Additionally, the crust is rumored to be healthier than the remainder of the bread. Some studies have shown that this is true as the crust has more dietary fibre and antioxidants such as pronyl-lysine [4,5], which is being researched for its potential colorectal cancer inhibitory properties [6,7].

Bread has significance beyond mere nutrition in many cultures because of its history and contemporary importance. Bread is also significant in Christianity as one of the elements (alongside wine) of the Eucharist, and in other religions including Paganism [8]. In many cultures, bread is a metaphor for basic necessities and living conditions in general. For example, a "bread-winner" is a household's main economic contributor and has little to do with actual bread-provision. This is also seen in the phrase "putting bread on the table". The Roman poet Juvenal satirized superficial politicians and the public as caring only for "*panem et circenses*" (bread and circuses) [8].

Potassium bromate ($KBrO_3$) is a flour improver that acts as a maturing agent. $KBrO_3$ acts principally in the late dough stage giving strength to the dough during the late proofing and early baking [9]. It takes the form of white crystals or powder. Potassium bromate has been used as a dough conditional for the past 60 years. According to the United States Department of Agriculture (USDA), it improves dough processing properties, internal crumb quality and low volume in concentration from a few to 75 ppm, the highest concentration permitted by law [10]. In early 1990's, the World Health Organization (WHO) discovered that potassium bromate if consumed has the capacity to cause such diseases as cancer, kidney failure and several other related diseases. The adverse effect of potassium bromate on health and its

health effects are divided into two categories. The first category deals with effects related to non-cancer effect. This includes its effect on the nutritional quality of bread. It degrades vitamin A_2, B_1, B_2 and niacin which are the main vitamins available in bread. This led to its ban by the WHO in 1992 [11]. Studies have shown significant difference in essential fatty acid content of flour treated with bromate or in bread made from flour containing bromate and those free of bromate [11]. In humans, potassium bromate has been reported to cause cough and sore throat when inhaled [12]. It has also been reported to cause abdominal pain, diarrhea, nausea, vomiting, kidney, etc. [12]. In the secondary category, some studies has reported the potential of potassium bromate to cause cancer in experimental animals and in humans [13,14]. Using bromate as bread improver in Nigeria has been banned by NAFDAC in 2003 [15]. However, some bakeries have continued to add potassium bromate in their products. This study is therefore aimed at investigating the level of compliance to this ban fifteen years after.

2. METHODOLOGY

2.1 Study Area

Ibadan is the capital and most populous city of Oyo State, Nigeria. With a population of over 3 million, it is the third most populous city in Nigeria after Lagos and Kano; it is the country's largest city by geographical area. At the time of Nigeria's independence in 1960, Ibadan was the largest and most populous city in the country, and the second most populous in Africa after Cairo. Ibadan is located in south-western Nigeria, 128 km inland northeast of Lagos and 530 km southwest of Abuja, the federal capital, and is a prominent transit point between the coastal region and the areas in the hinterland of the country. Ibadan had been the centre of administration of the old Western Region since the days of the British colonial rule, and parts of the city's ancient protective walls still stand to this day. The principal inhabitants of the city are the Yorubas, as well as various communities from other parts of the country. Ibadan is an urban centre and the production and consumption is very high.

2.2 Methods

A total of thirty brands of breads were used in this study. They were purchased randomly from bakeries, bus stops, and markets in Ibadan, the Oyo State capital, Nigeria. Potassium bromate in the bread samples was qualitatively and quantitatively analyzed using previously reported methods [16]. A 1.0 g quantity was weighed out from each bread sample in an electronic weighing balance. This was transferred into a test tube. 10 ml of distilled water was added; the mixture was shaken and allowed to stand for 20 minutes at 28 $\pm$ 10 °C. A 5.0 ml volume was decanted from the test tube. A 5.0 ml quantity of freshly prepared 0.5 % potassium iodide solution in 0.1N hydrochloric acid was added. Any colour change was noted. The presence of potassium bromate was indicated by change in colour from light yellow to purple [16]. The absorbance of the sample was taken at 620 nm in a colorimeter (CAM-Spec. M330). Absorbance of the sample was converted to concentration with reference to Beer's calibration curve previously constructed for potassium bromate using the pure sample [16]. Values presented are mean of five replicate determinations.

3. RESULTS AND DISSCUSION

Potassium bromate is a flour enhancer that acts as a maturing agent. It acts mainly in the late dough stage by giving strength to the dough during late proofing and early stage of baking [17]. During the preparation of the bread, the formation of protein molecules joined together by disulphide linkages results. The strength and elasticity of this network which gives the bread its characteristic properties is best when it comprises of long chain proteins such as gluten. Short chain peptides such as glutathione (a tripeptide) which are present as well react with gluten molecules breaking down the dough structure. This structural breakdown can be prevented by the addition of oxidizing agents [18, 19]. Potassium bromate is the most commonly used oxidizing agent. Vitamin C (ascorbic acid) can also be used but not as effective as potassium bromate. In the presence of any of these oxidizing agents, the glutathione is oxidized to glutathione disulphide and therefore cannot interfere with disulphide bonds of the gluten molecules [20]. But in the absence of these oxidizing agents, the reverse is the case.

Potassium bromate in the sample complexed with potassium iodide to give a purple colouration. Potassium bromate in bread reacts with promethazine hydrochloride in the acidic medium to form a purple coloured product [19]. The degree of colouration increases with increase in concentration of potassium bromate.

The intensity of the colour change is directly proportional to the concentration of potassium bromate present in the sample [21]. The result of the qualitative determination of potassium bromate in the 30 bread samples is presented in Table 1. It was observed that three of the thirty bread samples (samples N, Q and V) did not give any visible colour change when reacted with potassium iodide. It might be that they contained no potassium bromate or that it was present in the samples in residual amount that could not be detected by the reagent [19]. All the other samples indicated positive result for the presence of potassium bromate, but the intensity of the purple colour produced differs. This implies that potassium bromate is present in the various bread samples in varying degrees [22]. Table 1 also shows the result of the quantitative determination of potassium bromate present in each bread sample. The concentration of potassium bromate in all the thirty bread samples analyzed is greater than 0.02 µg/g, which is the permissible safe level of potassium bromate allowed in bread by the United States' Food and Drug Agency (FDA) [23] and it also contravenes the NAFDAC ban on use of potassium bromate in bread [15]. This means that, none of the bread samples in Ibadan analyzed in this study is safe for human consumption as far as potassium bromate content is concerned. The sample with the smallest concentration of $KBrO_3$ contains 1.24 µg/g (which is more than 60 times higher than the permissible safe level) and the highest concentration contains 9.31 µg/g (which is more than 465 times higher than the permissible safe level).

Table 1. Qualitative and quantitative determination of potassium bromate in some brands of bread produced and/or sold in Ibadan, Nigeria

Bread samples	Colour change (Qualitative test)	Quantity of $KBrO_3$ (µg/g)
A	Dark Purple	8.12 ± 0.25
B	Purple	5.48 ± 0.37
C	Purple	5.82 ± 0.41
D	Purple	6.03 ± 0.33
E	Purple	6.00 ± 0.91
F	Light Purple	2.64 ± 0.52
G	Purple	3.98 ± 0.29
H	Purple	4.96 ± 0.31
I	Dark Purple	7.89 ± 0.28
J	Light Purple	2.76 ± 0.41
K	Purple	5.41 ± 0.50
L	Purple	6.64 ± 0.25
M	Purple	5.72 ± 0.39
N	No visible colour change	1.82 ± 0.33
O	Purple	3.66 ± 0.25
P	Dark Purple	9.31 ± 0.43
Q	No visible colour change	1.24 ± 0.31
R	Purple	5.18 ± 0.22
S	Purple	6.00 ± 0.09
T	Purple	5.69 ± 0.28
U	Purple	3.66 ± 0.23
V	No visible colour change	1.98 ± 0.15
W	Purple	5.66 ± 0.25
X	Dark Purple	8.73 ± 0.38
Y	Purple	5.46 ± 0.30
Z	Purple	3.82 ± 0.35
AA	Purple	4.96 ± 0.40
BB	Dark Purple	8.88 ± 0.38
CC	Purple	5.76 ± 0.25
DD	Purple	5.89 ± 0.39
EE	Purple	6.46 ± 0.30

Values are presented as mean ± standard deviation with n = 5. Letter A to EE represents the code for different brand of bread sample analyzed

One interesting but contradicting finding of this study is that the bread samples with "bromate free" in their labels actually contain higher potassium bromate than those without such inscription on their labels. This shows the level of insincerity in the bakery industry in Ibadan and Nigeria in general. Fourteen of the thirty bread samples used in this study representing 46.67% were not registered with the National Agency for Food, Drug Administration and Control (NAFDAC), the agency responsible for regulating drugs, foods and chemicals in Nigeria as they had no NAFDAC registration number on their label while some had no label at all. Since they are not registered with the regulatory body, there is no way they could comply with the regulations of the body. Nine of the thirty bread samples used in this study representing 30.00% had no label in them. This might also mean that they are not registered with NAFDAC.

The amount of potassium bromate present in bread samples obtained in this study is similar to the 1.2 µg/g and 10.4 µg/g for the lowest and highest level of potassium bromate obtained from bread samples analyzed in Eastern part of Nigeria by Emeje et al. [24]. It is however lower than the values of 3.7 µg/g and 12.6 µg/g reported for minimum and maximum quantity of potassium bromate respectively, obtained in bread samples consumed in Kaduna metropolis as reported by Ojeka et al. [25]. Considering the elevated level of $KBrO_3$ present in the analyzed bread samples in conjunction with the fact that bread is a staple food consumed on a daily basis by residents and inhabitants of Ibadan metropolis irrespective of their status, we can deduce that there might be high dietary exposure of Ibadan residents to potassium bromate via bread consumption. Similarly, bakery workers might also be exposed to serious risk from inhaled bromate. As a result of this, there may be future occurrence of carcinogenicity and other symptoms associated with chronic exposure to high level of potassium bromate in Ibadan [19].

The determination of potassium bromate in bread samples above the permissible safe level might implies that the compliance of bakery industry with NAFDAC ban on the use of potassium bromate in bread after fifteen years is poor and the agency need to step up their regulatory activities and ensure adequate enforcement of this ban [19]. Potassium bromate present in bread is harmful to consumers of bread because it has been associated with neurotoxicity and nephrotoxicity [26], as well as ototoxicity [27], and it poses additional threat to the health of bakery workers as potassium bromide, a heat decomposition product of potassium bromate, is also toxic [28]. Furthermore, potassium bromate reduces the nutritional quality of bread by degrading essential vitamins such as vitamin A, B and E [29].

Oloyede and Sunmonu [30] also reported adverse effects of potassium bromate on liver and kidney functions of rats fed on diet formulated with bread containing potassium bromate. In a study by Ayo et al. [31], vitamin C competes favourably with potassium bromate in enhancing the quantity of bread. On the basis of cost, vitamin C can be considered a more effective enhancer of dough even though bromate can achieve a higher loaf volume on equivalent weight basis. With respect to the many harmful effects of $KBrO_3$, other oxidizing agents, such as vitamin C, that is non-toxic and equally guaranteed improved quality and value of bread can be used in place of $KBrO_3$. In the same vein, enzymes such as hemicellulases (volume enhancing), glutathione oxidase (protein strengthening) and exopeptidase (improves colour and flavour) can equally be used [19].

4. CONCLUSION

It is concluded that study shows all the thirty loaves of bread sampled, had potassium bromate in concentration above safe level for human consumption, therefore bread consumers and bakers in Ibadan and indeed Nigeria are at risk of exposure to potassium bromate with health implications. The need for continuous surveillance and enforcement of the ban on use of potassium bromate in baking industry in Nigeria is recommended.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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