



## **Spectrophotometric Determination of the Concentrations of Potassium Bromate (KBrO<sub>3</sub>) in Breads Sold in Mubi Metropolis, Adamawa State – Nigeria**

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### ***Abstract***

Nine loaves of bread were randomly selected and purchased from bakeries/sales outlets resident in Mubi metropolis. They were dried at 105°C for 24 hours before separately grounded into fine powder and analyzed for the presence of potassium bromate (KBrO<sub>3</sub>) using the qualitative technique. A purple colour confirmed the presence of KBrO<sub>3</sub> before their absorbance was measured at 620nm using a UV-vis spectrophotometer. Results of the analysis showed X<sub>1</sub> = 0.0144, X<sub>2</sub> = 0.0230, X<sub>3</sub> = 0.0470, X<sub>4</sub> = 0.0190, X<sub>5</sub> = 0.0673, X<sub>6</sub> = 0.0013, X<sub>7</sub> = 0.0456, X<sub>8</sub> = 0.0835 and X<sub>9</sub> = 0.0353 respectively. These results were then converted to concentrations (ppm) with reference to a calibration curve constructed for KBrO<sub>3</sub> using the pure sample. Results from the studies showed, X<sub>1</sub> = 0.0157, X<sub>2</sub> = 0.0251, X<sub>3</sub> = 0.0513, X<sub>4</sub> = 0.0208, X<sub>5</sub> = 0.0735, X<sub>6</sub> = 0.0014, X<sub>7</sub> = 0.0498, X<sub>8</sub> = 0.0912 and X<sub>9</sub> = 0.0386. The results raise significant health and regulatory concerns. Low level usage can leave traces that pose health hazard (FAO/WHO, 2016), the use of KBrO<sub>3</sub> as a flour-treatment agent “is not acceptable” due to detectable residues in a baked bread and associated carcinogenic risk, (WHO/FAO JECFA, 1995). Therefore, the presence of KBrO<sub>3</sub> at these levels in breads widely consumed in Mubi underscore the importance of rigorous enforcement and consumer awareness.

**Keywords:** Analysis, texture, enhancer, bromate, spectrophotometer.

## Introduction

In the bakery industry,  $\text{KBrO}_3$  is an inorganic compound that is less cost effective, serves as a dough conditioner and an oxidizing agent for bread production. It strengthens the dough, improve its elasticity and enhance the rise of the bread by promoting the development of gluten, American Bakers Association (ABA, 2008). However, the use of  $\text{KBrO}_3$  became controversial due to the potential health risks it poses to its consumer. Further, it is classified by the International Agency for Research on Cancer (IARC) and World Health Organization (WHO) as a possible human carcinogen (IARC, 1999). Several studies on experimental animals has linked nephrotoxicity and carcinogenicity on  $\text{KBrO}_3$  and consequently classified as a possible human carcinogen (Class B) by the International Agency for Research on Cancer (IARC) in 1999.  $\text{KBrO}_3$  has been banned or restricted in several countries (over 30 countries) due to health concerns, particularly its carcinogenic potential, CODEX Alimentarius, 2002; FAO/WHO, 2005.

$\text{KBrO}_3$  is a white crystalline powder made up of potassium ( $\text{K}^+$ ), bromine (Br) and oxygen (O) that acts as a strong oxidizing agent in dough and it promotes chemical reactions that improve bread texture and volume. It is normally added in parts per million (ppm) to flour during bread production. It oxidizes and help strengthen the gluten network to produce better dough handling and a higher, more uniform loaf structure. It oxidizes by accepting electrons from other molecules in the bread especially, thiol (-SH) groups in gluten proteins and form the disulfide bonds (-S-S-) that strengthens the gluten network

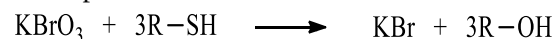
resulting in dough elasticity and gas retention with a better rise and texture, Cauvain, and Young, (2007).

Reaction:

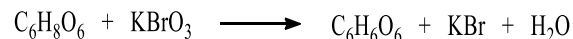


where;  $\text{R-SH}$  = thiol groups in gluten proteins,  $\text{R-S-S-R}$  = disulfide bond formed. From the equation,  $\text{KBrO}_3$  is reduced to  $\text{KBr}$ , a less reactive compound.

During the baking process,  $\text{KBrO}_3$  is reduced to  $\text{KBr}$  under heat and in the presence of reducing agents such as yeast or flour components. The reduction is very important as it reduces the residual bromate; in the final bread product.



where,  $\text{R-SH}$  = reducing agents (e.g., thiols or other flour components) and  $\text{R-OH}$  = oxidized products. In instances where alternative dough conditioner is used e.g. ascorbic acid (vitamin C),  $\text{KBrO}_3$  works in synergy with vitamin C by oxidizing it to dehydroascorbic acid, which further promotes disulfide bond formation in gluten, Mathewson, (2000).



here  $\text{C}_6\text{H}_8\text{O}_6$  = ascorbic acid and  $\text{C}_6\text{H}_6\text{O}_6$  = dehydroascorbic acid.

### Mechanism

$\text{KBrO}_3$  slowly oxidize the thiol groups during mixing thereby strengthening the gluten network leading to an improve dough elasticity and handling properties. This process continues to act with resultant gas

retention by stabilizing the gluten structure which leads to better loaf volume. In the baking process, the heat in the oven accelerates the reduction of  $\text{KBrO}_3$  to  $\text{KBr}$  which reduce the residual bromate levels. But incomplete reduction leaves trace amounts of bromate and this raises health concerns from by some health organizations (such as IARC and WHO).

Research from studies on the determination of concentration of  $\text{KBrO}_3$  in breads in order to assess the level of compliance with acceptable standards has shown that, despite the International restrictions, the compound has continued to be used by bakers in Nigeria and several other developing countries due the less stringent or inconsistent enforcement of the restrictions by agencies saddled with the responsibility. For example,  $\text{KBrO}_3$  was officially banned by NAFDAC since 1993, but studies have showed non-compliance with the ban, (Moses *et al.*, 2023); studies confirmed its excessive use in Bamenda, North West Region of Cameroon, (Therese, Percline, & Kenneth, 2023); it has been detected in residues of bread samples in Dhaka City, Bangladesh, (Abu *et al.*, 2020); India and Indonesia still use it, (Market Growth Reports, 2024); on-going use in countries like Ghana and Tanzania, and in Libya, it has been detected in bread from Benghazi bakeries (Cognitivemarketresearch, 2025); (Cuisine for Healing, n.d.).

The presence and concentration of potassium bromate ( $\text{KBrO}_3$ ) in bread, with particular focus on sub-Saharan Africa and Nigeria, to provide context for determining its levels in breads sold in Mubi Metropolis, Adamawa State is reviewed herein.

$\text{KBrO}_3$  is not only a flour improver and dough conditioner but a powerful oxidizing agent widely used in the baking industry due to its ability to enhance bread volume, texture and crumb structure (Onwuka, 2005). It is considered a possible human carcinogen (Group 2B) by the International Agency for Research on Cancer (IARC) due to results from researches conducted on experimental animals over the years that indicated its toxicological effects that includes nephrotoxicity and carcinogenicity (Lilja *et al.*, 1986; Umemura *et al.*, 1997). Despite the health risks involved,  $\text{KBrO}_3$  is still used illegally in some countries, (in developing economies where regulatory enforcement is weak and inconsistent). In Nigeria for instance, the National Agency for Food and Drug Administration and Control (NAFDAC) ban its use in food products since 2002, (NAFDAC, 2002). Empirical evidence from studies suggested its continued usage by the small-scale bakers due to its low cost and effectiveness compared to ascorbic acid and azodicarbonamide that are recommended as alternative agents (Eneobong *et al.*, 2012; Njoku *et al.*, 2016).

### **$\text{KBrO}_3$ chemical properties and function in bread production**

$\text{KBrO}_3$  is a white crystalline powder that is soluble in water and works as a slow-acting oxidizing agent during bread baking process. It strengthens the gluten network of bread thereby improving its dough elasticity and enhancing gas retention that leads to a better loaf volume and crumb structure (Adebawale & Adeyeye, 2010). In the oven during baking, it is expected that  $\text{KBrO}_3$  should decompose into a non-toxic bromide ion ( $\text{Br}^-$ ) but, if the temperature in the oven is inadequate or in excess, residual  $\text{KBrO}_3$  may retain in the final

product. Research have shown that this poses a health risk to the consumer (Codex Alimentarius Commission, 1999).

#### **Side effects associated with $\text{KBrO}_3$**

Several studies have indicated that  $\text{KBrO}_3$  induces oxidative stress and DNA damage in kidney cells that lead to tumor formation in experimental animals (Matsui *et al.*, 1986; Umemura *et al.*, 1997). The findings from these studies informed the decision of the regulatory bodies worldwide to ban its use in food processing. A maximum permissible level of 30 mg/Kg of residual  $\text{KBrO}_3$  in bread was set by the Codex Alimentarius Commission (CAC, 1999), while the European Union and other countries have completely prohibited its use (FAO/WHO, 2001).

In Nigeria, despite its ban, studies from several researches have shown a widespread use of the compound leading to contamination of bread samples. Eneobong *et al.*, (2012) reported 74% of bread samples from Lagos containing detectable levels of  $\text{KBrO}_3$  whose concentrations ranged between 22.3-85.4 mg/Kg. Equally, Njoku *et al.*, (2016) reported 68% of bread samples from Abuja exceeding the Codex limit.

These findings goes to show the persistent violation of food safety regulations and underscore the urgent need for a more rigorous, efficient monitoring and enforcement of the restriction, especially at the local level.

#### **Methods for the detection of $\text{KBrO}_3$ in bread**

Among the several analytical techniques developed for the detection and quantification of  $\text{KBrO}_3$  in bread samples, iodometric titration remained one of the most commonly used method due to its simplicity, accuracy and cost-effectiveness (AOAC, 2000). The method involve oxidising iodide ions to iodine in acidic medium using the bromate solution which is then followed by titration with sodium thiosulfate ( $\text{Na}_2\text{S}_2\text{O}_3$ ) to determine the amount of bromate present. Other advanced techniques includes the high-performance liquid chromatography (HPLC), spectrophotometry and ion chromatography. These techniques offers a higher sensitivity and specificity but requires sophisticated equipment not always available in regions where there is limited resources (Adeoye & Spiff, 2003).

#### **Studies and use of potassium bromate ( $\text{KBrO}_3$ ) in the Nigerian baking industry**

Results of studies conducted across the different regions in Nigeria have shown  $\text{KBrO}_3$  to be consistently present in breads; in Lagos, Eneobong *et al.*, (2012) found 30 (75%) out of the 40 bread samples analysed to contain detectable levels of  $\text{KBrO}_3$ , and 18 samples exceeding the Codex limit; in Abuja, Njoku *et al.*, (2016) reported 68% of bread samples having  $\text{KBrO}_3$  levels above 30 mg/Kg and some of the samples reached up to 102 mg/Kg; in Enugu, Okoye *et al.*, (2010) detected in their study,  $\text{KBrO}_3$  in 60% of bread samples with concentrations within the range 25.4-78.9 mg/Kg and in Port Harcourt, Adeoye and Spiff (2003) discovered 55% of bread samples contaminated with  $\text{KBrO}_3$  with mean concentrations of 43.6 mg/Kg.

These findings is an indication that the issue of  $\text{KBrO}_3$  presence in bread samples across the nation requires targeted interventions streamlined to the local production practices and regulatory capacities.

From the foregoing, it could be assumed that  $\text{KBrO}_3$  remains a significant public health concern in Nigeria, especially in urban and semi-urban centres where bakeries are widespread in use. Despite the regulatory bans and International warnings, the illegal use of  $\text{KBrO}_3$  persists due to the weak enforcement and inconsistent mechanisms by regulatory agencies and lack of viable alternatives. The situation in Mubi Metropolis in Adamawa State, northeast of Nigeria echoes a national trend that necessitates localized investigation and interventions. The present study is aimed at the determination of the concentrations of potassium bromate ( $\text{KBrO}_3$ ) in breads sold in Mubi metropolis.

The illegal use of  $\text{KBrO}_3$  in the Nigerian bakeries can be attributed to the poor and inconsistent enforcement of food safety regulations, lack of information/awareness among bakers, and limited access to safer alternatives (Eneobong *et al.*, 2012). Many small-scale bakers continue to rely on  $\text{KBrO}_3$  because it is cheaper than the permitted additives and it significantly improves the quality of bread made from low-protein flours (Njoku *et al.*, 2016).

The absence of routine inspections and testing facilities at the state and local government levels further exacerbates the problem. While Federal agencies like NAFDAC have issued bans and guidelines, implementation at the grassroots remains minimal (Okonkwo & Oranekwu, 2004).

The study reported herein is aimed at the determination of the concentrations of potassium bromate ( $\text{KBrO}_3$ ) in breads produced and sold in Mubi Metropolis, Adamawa State – Nigeria. Its objectives are; to determine the concentrations of potassium bromate ( $\text{KBrO}_3$ ) in breads spectrophotometrically, assess the level of compliance by the bakeries with acceptable standards and to provide data that could inform policy decision makers saddled with the responsibility of food safety in the region.

## **Materials and Method**

### **Sample Collection**

Bread samples from bakeries and sales outlet resident in Mubi were randomly purchased from various bakeries and bread vendors across Mubi Metropolis to ensure representative sampling. The samples were removed from their plastic bags and dried in an oven ( $105^\circ\text{C}$ ) for 24 hours before they were separately crushed into powder, weighed and stored for further analysis. The following breads were analysed; Zamani, Ni'ima, Husna, Siyawa, Milk, Rahma, Tukana, Mubi Special and Kanki Nais bread respectively. In the result of the analysis, the breads were not identified for obvious reasons.

### **Analytical Method**

The methods of Ekere *et al.*, 2022; Musa *et al.*, (2022) and Lami *et al.*, 2022 was adopted with slight modification for the analysis. 1.0 g of a bread powder was weighed into a test tube before  $10\text{ cm}^3$  of distilled water was added to it. The mixture was shaken and allowed to stand

at  $28 \pm 10$  °C in a water bath for 20 minutes before it was removed, cooled and 5 cm<sup>3</sup> of freshly prepared 5 % potassium iodide (KI) solution in 0.1 M HCl was added, the change in colour of the solution from the light yellow colour of KI to purple colour of the oxidized KI indicates the presence of KBrO<sub>3</sub> in a sample, Ekere *et al.*, 2022. The absorbance of the sample was taken at 620 nm in UV spectrophotometer. The absorbance of the sample was then converted to concentration with reference to calibration curve constructed for potassium bromate using the pure sample.

#### Preparation of standard solution of KBrO<sub>3</sub>

Standard solution of KBrO<sub>3</sub> (1000 µg/ml) (99.8 % purity, Merck) was first prepared in distilled water as the stock solution before intermediate stock standard solution (50 µg/ml) was prepared from it. Different aliquots (0 ml, 20 ml, 40 ml, 60 ml, 80 ml, 100 ml) from the intermediate stock standard solution was separately measured and poured into a 100 ml volumetric flask and diluted to 80 ml before 1.0 ml of 0.01M promethazine (PMZ) followed by 0.2 ml of 12M HCl were added into each flask and made up to the mark with distilled water. The solution formed were then shaken for 1 minute before its absorbance was measured at 515 nm against a reagent blank. A standard curve was plotted and the regression equation was generated. This method employed was as described by El Harti *et al.*, (2011).

## RESULTS

Table 1. **Properties of the Bread Sample**

| Sample | Physical properties         | Qualitative tests |
|--------|-----------------------------|-------------------|
| 1      | brown color, soft and moist | faint purple      |
| 2      | brown color, soft and moist | faint purple      |
| 3      | brown color, soft and moist | purple            |
| 4      | brown color, soft and moist | purple            |
| 5      | brown color, soft and moist | faint purple      |
| 6      | brown color, soft and moist | purple            |
| 7      | brown color, soft and moist | purple            |
| 8      | brown color, soft and moist | faint purple      |
| 9      | brown color, soft and moist | faint purple      |

Table 2. **KBrO<sub>3</sub> Standard**

| Conc. (ppm) | Absorbance |
|-------------|------------|
| 0           | 3.001      |
| 20          | 25.020     |
| 40          | 45.001     |
| 60          | 65.001     |
| 80          | 85.002     |
| 100         | 110.002    |

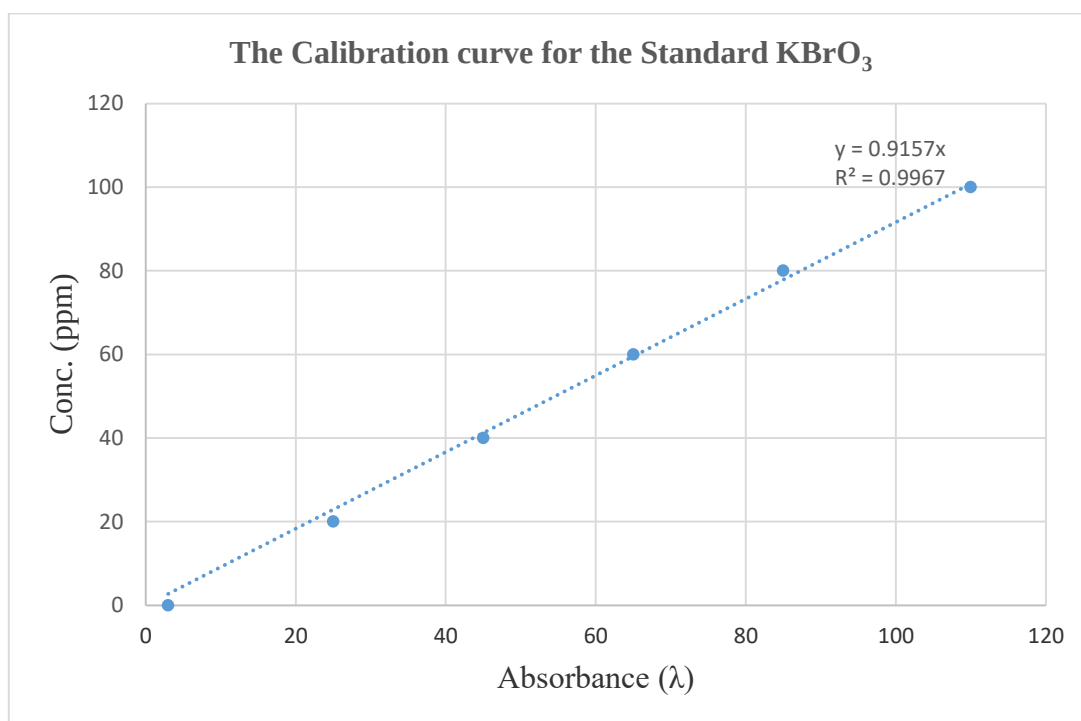


Fig.1. Calibration curve for the Standard KBrO<sub>3</sub>

**Table 3.** Concentrations of the Samples

| Sample         | Absorbance (nm) | Calc. conc. (mg/Kg) |
|----------------|-----------------|---------------------|
| X <sub>1</sub> | 0.0144          | 0.0157              |
| X <sub>2</sub> | 0.0230          | 0.0251              |
| X <sub>3</sub> | 0.0470          | 0.0513              |
| X <sub>4</sub> | 0.0190          | 0.0208              |
| X <sub>5</sub> | 0.0673          | 0.0735              |
| X <sub>6</sub> | 0.0013          | 0.0014              |
| X <sub>7</sub> | 0.0456          | 0.0498              |
| X <sub>8</sub> | 0.0835          | 0.0912              |
| X <sub>9</sub> | 0.0353          | 0.0386              |

### Discussions

About nine bread samples randomly purchased from bakeries and outlets resident in Mubi and other locations outside Mubi metropolis were sampled and analyzed for the presence potassium bromate (KBrO<sub>3</sub>) and their concentrations calculated from the graph of a calibration curve for a standard solution of KBrO<sub>3</sub> (Table 2). The breads were brown in color, soft to touch, moist in texture and produced faint purple/purple colors when reacted with solutions of 5 % potassium iodide (KI) solution in 0.1 M HCl (Table 1). The change in colour of the solution from the light yellow colour of KI to purple colour of the oxidized KI was taken as an indication of the presence of KBrO<sub>3</sub> in the sample, (Ekere *et al.*, 2022; Musa *et al.*, (2022); Lami *et al.*, 2022).

The calibration curve (fig. 1) plotted for the standard  $\text{KBrO}_3$  solution (Table 2) showed a linear relationship between concentration (ppm) and absorbance based on the formula  $y = 0.9157x$ . This plot confirmed that the absorbance increases proportionally with the concentration, allowing for the use of the formula  $x = y/0.9157$  (generated from the trendline) to determine the concentration of an unknown sample using its measured absorbance, where  $y$  is the absorbance and  $x$  is the concentration (ppm). Therefore,  $x = \frac{y}{0.9157}$ .

The concentrations of potassium bromate (Table 3) in the bread samples using the equation are,  $X_1 = 0.0157$ ,  $X_2 = 0.0251$ ,  $X_3 = 0.0513$ ,  $X_4 = 0.0208$ ,  $X_5 = 0.0735$ ,  $X_6 = 0.0014$ ,  $X_7 = 0.0498$ ,  $X_8 = 0.0912$  and  $X_9 = 0.0386$  respectively. The range of values from approximately 0.0157 mg/kg to 0.0912 mg/kg, raise significant health and regulatory concerns. The Joint FAO/WHO Expert Committee on Food Additives (JECFA) in 1992, concluded that the use of  $\text{KBrO}_3$  as a flour-treatment agent “is not acceptable” because it resides in baked bread and it is associated with carcinogenic risk (WHO/FAO JECFA, 1995). Subsequent reviews upheld this position and further noted that even low-level usage can leave traces that poses health hazards (Food Safety Helpline, FAO/WHO evaluation, 2016). Even though some bodies previously tolerated up to about 0.02 mg/kg (or 20 µg/kg) in bread, the interpretation by expert panels and regulatory bodies led to near-zero tolerance policies. A lot of studies in Nigeria and elsewhere have found bromate residues exceeding even the earlier 0.02 mg/kg threshold (Magomya *et al.*, 2020; Emeje *et al.*, 2010;). The measured concentrations in this study are all above 0.02 mg/kg in several samples (e.g., sample  $X_8$  at ~0.091 mg/kg) clearly exceed both FAO/WHO expert committee guidance and earlier reference limits. Nigeria’s National Agency for Food and Drug Administration and Control (NAFDAC) banned its use in bread production in 2003/2004 and reiterated this in later regulations including the 2023 and 2025 Bread Regulations, stating that “No person shall use potassium bromate in the production of bread”, this is why sample  $X_6 = 0.0014$  cannot be considered safe for consumption. It has issued multiple warnings and carried out enforcements that includes closing bakeries and seizing banned additives (Adeyeye statements, 2024; warehouse interceptions, Lagos, 2022).

## Conclusion

Conclusively, persistent bromate residues in bread are associated with carcinogenic risks (IARC group 2B), kidney failure and oxidative cellular damage (WHO/FAO). All the samples analyzed had bromate concentrations >0.02 mg/kg, this clearly violated NAFDAC regulations. For instance, sample  $X_8$  ~0.091 mg/kg is more than four times beyond the maximum earlier acceptable limit. Therefore, the presence of bromate at these levels in breads that is widely consumed in Mubi underscores the importance of rigorous enforcement and consumer awareness.

## Recommendations

- NAFDAC should intensify post-marketing surveillance, unannounced bakery inspections, and laboratory testing to identify non-compliant bread-makers (Adeyeye, 2024).



- Consumers should be educated about risks of bromate use and how to identify “bromate-free” products.
- Bakers should be compelled to make a transition to safer flour-improving agents such as ascorbic acid or enzymes that offer similar dough benefits without residue risk.

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