

**DETERMINATION OF POTASSIUM BROMATE IN UNSLICED
BREAD IN EGOR LOCAL GOVERNMENT**

BY

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CERTIFICATION

We the undersigned certify that SUNDAY IZEDONMWEN ESOSA (BMS2009415) carried out this research in the Department of Medical Biochemistry, School of Basic Medical Sciences, University of Benin and thereby approve same as adequate in scope and quality for the award of Bachelor of Science Degree (B.Sc) in Medical Biochemistry

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DEDICATION

I dedicate this work to God Almighty who sustained me all through my time in the University of Benin and gave me the wisdom and enablement to successfully carry out this research and my lovely parents, Mr Sunday Izedonmwun and Mrs Ruth Izedonmwun, as well my aunt, Mrs Helen Ekhaguere for their immeasurable support and contributions to my academic success so far, to my lovely brother and friends for all their encouragements and advice.

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ABSTRACT

Potassium bromate, a chemical once commonly used as a flour improver, has been banned in many countries due to its harmful health effects, including its potential to cause cancer and organ toxicity. Despite these regulations, concerns persist about its continued use in bread production, particularly in small-scale bakeries. This study investigates the presence and concentration of potassium bromate in unsliced bread samples obtained from various bakeries in Egor Local Government Area, using both qualitative and quantitative analytical methods. Bread samples were collected and categorized based on their loaf sizes, with qualitative analysis conducted to detect the presence of potassium bromate. The results revealed that while some samples showed no reaction, others exhibited a blue-black coloration, confirming the presence of potassium bromate. Quantitative analysis further indicated varying concentrations across the tested samples, with some exceeding the acceptable safety threshold. The highest concentration recorded was 0.04 mg/kg, raising significant health concerns. These findings suggest that despite regulatory efforts, potassium bromate is still being used in some bread production processes, potentially putting consumers at risk. The study highlights the need for stricter enforcement of food safety regulations, increased public awareness, and the promotion of safer alternatives in bread-making. Strengthening routine monitoring and implementing more stringent penalties for non-compliance could help eliminate potassium bromate from the food supply chain, ultimately safeguarding public health.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Bread is a food that humans have consumed for ages. It is so popular that it is consumed in almost every house in Nigeria as breakfast, every morning. This is most likely attributed to the fact that it is readily available, cheap, and is one of the quickest meals. To make bread, yeast is mixed with wheat dough and then baked. Baking high-quality flour, which is determined by the prepared dough's ability to hold onto gasses, is one of the main problems impacting bakeries and grain millers (Johnson *et al.*, 2013). When making bread, ingredients known as food additives are added to improve the bread's flavor and lengthen its shelf life. Potassium Bromate (KBrO_3) is the most commonly used additive because it has a high oxidizing action and does not adversely affect bread's taste, flavor, or appearance. Apart from that, it also improves the smoothness and the upward consignment of the bread during baking (Dagari *et al.*, 2022). Furthermore, its preferred usage is caused by the fact that it is by far cheaper than ascorbic acid and glucose oxidase (CSE Study, 2016). It can be used as a dough conditioner and maturation agent simultaneously because, through oxidation, its gluten protein's sulfhydryl groups become disulfide bridges (Kurokawa *et al.*, 1990), making the dough more elastic and less extensible. Thus, the dough becomes viscoelastic and collects the carbon (IV) oxide yeast yields. The overall purpose of adding these substances is to cause the dough to expand or rise as well as improve the texture and actual size of the loaf produced (Dagari *et al.*, 2022; Irogbeyi *et al.*, 2019).

The International Agency for Research on Cancer (IARC) has classified KBrO_3 as a poisonous and carcinogenic compound (Group 2B compound) (Abdel-Latif *et al.*, 2021) after it was found that increased intake of potassium bromate is very harmful to human health because it has a higher tendency to induce cancer (Nkwatoh *et al.*, 2023).

Previous studies have shown that bromate facilitates the functionality of lower-quality gluten to mimic that of higher-quality gluten (Dahiya *et al.*, 2020). Additionally, it has been reported that potassium bromate exerts hepatotoxic, genotoxic, and nephrotoxic effects in both human and animal models (Oloyede & Sunmonu, 2009; O, Oyewo *et al.*, 2013). Eventually, it resulted in the banning of the usage by the Joint Committee of the Food and Agricultural Organization (FAO) and the World Health Organization (WHO) (FAO/WHO, 1999).

In Nigeria, despite the ban on the use of the compound and the high burden of fatalities from chronic diseases such as chronic kidney disease (CKD), chronic liver disease (CLD), cardiovascular disease (CVD), and other cancer-related deaths, many bakeries in Nigeria are using this compound. It is evidently shown by reports of a high level of potassium bromate in bread in several studies conducted after the research, such as studies by Alli *et al.*, (2013), Emeje *et al.*, (2015), Dada *et al.*, (2017) Nosa *et al.*, (2018), Uduak, (2019), Uwah and Ikwebe, (2020), Abduljalil *et al.*, (2021), Dagari *et al.*, (2022), and Lateefat *et al.*, 2022. This study sets out to determine the quantitative and qualitative levels of $KBrO_3$ in different bread samples in Egor Local Government Area, Benin City, Edo State to ascertain the prevalent use of Potassium bromate.

AIM OF STUDY

The purpose of this research is to conduct a comprehensive quantitative and qualitative analysis of Potassium Bromate in commercially available bread samples sold in Egor Local Government Area, Benin City, Edo state, Nigeria, with the goal of determining the presence of such compound in bread and quantifying its level if present.

CHAPTER TWO

TWO LITERATURE REVIEWS

2.1 BREAD – MANKIND OLDEST STAPLE FOOD

Bread is a staple food created by baking dough composed of flour, water, and sometimes salt and other ingredients. The dough typically undergoes fermentation, either naturally or using leavening agents (Cauvain and Young, 2005). Bread, one of the oldest human-made foods, has been a key dietary staple since the advent of agriculture. Its preparation has evolved over time, incorporating diverse ingredients and methods across cultures, where it holds significant importance in daily life and religious traditions.

2.1.1 HISTORICAL BACKGROUND OF BREAD

Bread has ancient origins, dating back over 14,000 years to the prehistoric era when early humans first prepared flatbreads from wild grains (Phys.org, 2010). These early flatbreads were unleavened, simple mixtures baked on hot stones or in primitive ovens. Archaeological evidence suggests that the practice of grinding grains and baking predates the development of agriculture, making bread one of the earliest forms of processed food. Indigenous cultures, such as Australia's Aboriginal communities, have also preserved ancient culinary traditions that connect food with spiritual and cultural practices (The Guardian, 2016).

As agriculture advanced, bread evolved from its primitive flat form to include leavening, which transformed its texture and flavor. The Egyptians are credited with pioneering the use of natural fermentation to produce leavened bread, a process that likely emerged around 6,000 years ago (McGee, 2004). This innovation allowed bread to become softer and more palatable, leading to its widespread adoption. Bread quickly became a dietary

staple and gained cultural and religious importance, especially in ancient civilizations such as Egypt and Rome, where advancements in milling and baking further refined its production (Tannahill, 1973). Over centuries, bread-making techniques diversified, reflecting regional ingredients and preferences. The Industrial Revolution brought about significant changes in production, culminating in the 20th-century invention of the Chorleywood Bread Process, which revolutionized bread manufacturing by reducing fermentation time (BBC News, 2011). Despite these advancements, traditional bread-making practices remain a vital part of cultural heritage, emphasizing the enduring significance of this staple food in human history.

2.1.2 HISTORY OF BREAD IN NIGERIA

Bread has become a beloved staple in Nigerian cuisine, but its origins in the country trace back to colonial influences in the early 20th century. Nigeria's first documented interaction with bread occurred during the colonial era, particularly in the 1920s, when expatriates introduced it to Lagos. This period saw the establishment of bakeries catering primarily to European tastes, with bread gradually finding its way into the diets of local Nigerians (Ejilola, 2023).

The post-independence period saw bread transitioning from an imported delicacy to a locally produced staple. This shift was driven by the establishment of local bakeries and increased urbanization, which created a growing demand for quick, convenient, and affordable food options. Bread's evolution in Nigeria was also influenced by the need to address challenges such as the high cost of wheat importation. Adeniji (2015) highlights innovative approaches, such as blending wheat with local ingredients like plantain and banana flour, which not only reduced dependency on imported wheat but also gave rise to unique bread varieties suited to Nigerian tastes.

As bread became more accessible, it also evolved into a cultural and economic symbol. Ejilola (2023) describes bread as a "darling" of Nigerians, reflecting its ubiquity

across all social strata. Whether sold by roadside vendors or displayed in upscale supermarkets, bread has bridged social and economic divides, symbolizing sustenance and resilience in the face of economic challenges. Its affordability and versatility make it a staple for many households, while fluctuations in its price often serve as an indicator of broader economic conditions.

Today, bread in Nigeria represents a fascinating blend of colonial influence, local innovation, and cultural adaptation. From its origins as a foreign luxury to its current status as an everyday necessity, bread has firmly established itself as a vital component of Nigerian life, embodying both the nation's historical journey and its adaptability to modern challenges.

2.2 BREAD VARIETIES

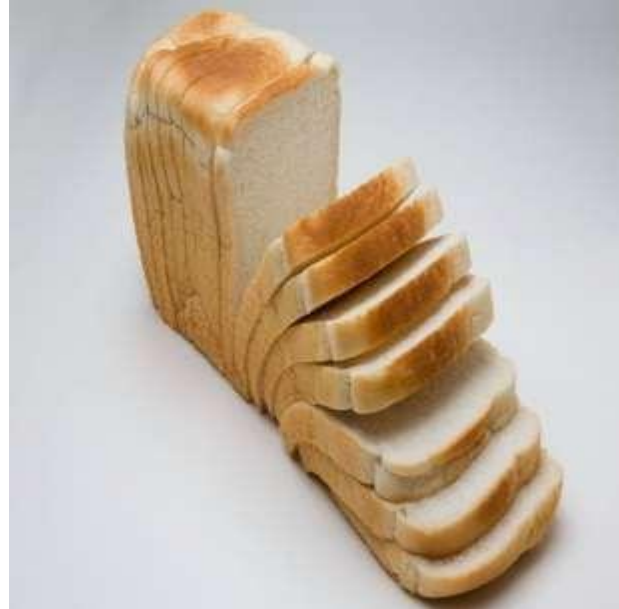
2.2.1 POPULAR TYPES OF BREAD

Bread comes in an astounding variety of types, reflecting the diversity of ingredients, preparation methods, and cultural traditions worldwide. Each type offers a unique flavor, texture, and use, making bread a versatile food enjoyed globally. Popular bread types include:

1. **White Bread:** White bread is a type of bread produced with refined wheat flour. The refinement process involves the removal of the bran and the germ layers from the whole wheatberry during the flour grinding or milling process, producing light-colored flour (NPCS Board, 2012).
2. **Whole Wheat/Wholemeal Bread:** Whole wheat or wholemeal bread is crafted using wholemeal flour, also known as whole-grain wheat flour. This flour is made entirely or partially from whole or nearly whole wheat grains (Health Canada, 2007). Unlike white bread, it retains the bran and germ, which contributes to its denser texture and deeper flavor (BakeInfo, 2011).
3. **Flatbread:** Flatbread, one of the oldest bread forms, is still widely consumed, particularly across the Middle East, Asia, and Africa. It is made using grains like corn

(maize), barley, millet, buckwheat, wheat, and rye. The lack of sufficient gluten in some of these grains makes them unsuitable for raised breads. Flatbreads can be either single-layered and typically unleavened or double-layered and leavened. These breads are versatile and serve various purposes, such as wrapping (e.g., tortilla), holding (e.g., pita, naan), or forming the base of meals (e.g., pizza).

4. Rye Bread: Originally developed in Europe, rye bread is a wholemeal bread prepared using rye flour or a combination of rye and wheat flour. Unlike standard flour, rye flour contains fewer dough-strengthening proteins, resulting in weaker dough. It also has higher levels of the enzyme amylase, which converts starch into sugars during baking.
5. Sourdough Bread: Sourdough bread is made by fermenting dough with naturally occurring lactobacilli and yeast before baking. The fermentation process produces lactic acid, giving the bread its signature sour taste and enhancing its shelf life (Gänzle, 2014).
6. Multigrain Bread: Multigrain bread is created using two or more types of grains, such as barley, flax, millet, oats, wheat, or whole-wheat flour. Some variations incorporate edible seeds, including flaxseed, quinoa, pumpkin seeds, and sunflower seeds. This combination of grains and seeds provides a rich texture and additional nutritional benefits (Kirkpatrick, 2014; Media, 2015; Katzin, 2010).
7. Bagels: Bagels, traditionally associated with Jewish communities in Poland, are round, yeast-leavened bread rolls with a distinctive doughnut shape (Balinska, 2008). They feature a crisp, glossy crust and a dense interior. Made with basic bread ingredients like flour, yeast, salt, and a sweetener, bagels owe their chewy, spongy texture to high-gluten flour. Their texture can be modified with the addition of eggs, milk, or butter.



A



B



C



D



E



F



G

Bread Varieties: White Bread, Whole Wheat Bread, Flatbread, Rye Bread, Sourdough, Multigrain Bread, and Bagels (A–G)

Sources: Tandoh, 2017, McKenney, 2024, Jawad, 2024, Daum, 2024, Raffa, 2014, The Curious Nook, n.d., Szewczyk, 2024.

2.2.1 POPULAR BREAD VARIETIES EATEN BY NIGERIA

Popular bread types in Nigeria, as noted by Alaka (2024), include:

1. White bread (Agege bread): A soft, fluffy bread with a spongy texture, often affordable and commonly enjoyed with beans or tea.
2. Raisin bread: Made with raisins and flavored with cinnamon, typically prepared using white flour or egg dough.
3. Whole wheat bread: A favorite among health-conscious individuals, this bread is made from whole grain flour and offers various health benefits.
4. Sliced bread: Conveniently pre-sliced, it is commonly used for sandwiches and toast, making it ideal for quick meals.
5. Sardine bread: A savory bread filled with sardines, often enjoyed as a quick, filling snack.
6. Coconut bread: A sweet bread with coconut flavor, usually served as a dessert or light snack.

2.3 COMPOSITION OF BREAD

Bread has a brown crust which is crispy, attractive and spongy in texture, pleasant smell, and moist touch with an elastic crumb structure (Martin, 2004). These characteristics are mainly influenced by dough gluten network formed during dough-making (McGee, 2004). Gluten forming proteins are for instance responsible for the structure of breads and therefore are part of the gluten network. On addition of water to flour the proteins glutenin and gliadin combine to form what is known as gluten, which is a continuous phase that is both elastic and extensible. This network captures carbon dioxide that is produced by yeast during fermentation, so that the dough will rise and become „light“. Glutenin has a quality of elasticity and gliadin gives extensibility to dough and they boost up dough capacity to hold gases to develop the desired open knitted structure of bread (McGee, 2004). Gas cells are

created when carbon dioxide builds up during fermentation and baking. The crumb of the bread that is its soft interior is a solid food foamed by gas. The size and distribution of these gas cells affect the texture of the bread. Qualitative characteristics of dough, including moisture content, extent of kneading, and fermentation time, determine the size of the gas cells, thus fine or open texture (Annett *et al.*, 2001). The crust, the outer part of bread, is formed during the baking process because of dehydration and the Maillard reaction. For example, bread has a high internal moisture content, and when the surface area rises and becomes hotter, the excessive moisture will turn into steam and leave the bread surface crusty and hard. At the same time, the Maillard reaction between amino acids and reducing sugars produces golden-brown crust with a special taste. High crust quality provides a crust part that contrasts with the bread crumb's tenderness, improving the sensory attributes of bread (Williams and Phillips, 2005).

Bread's chemical composition encompasses a variety of elements, each playing a unique role in its structure, flavor, and nutritional value. Bread is mostly made of carbohydrates in the form of starch. At fermentation stage, enzymes like amylase are used to hydrolyze starches into simpler sugars like maltose as well as glucose. These sugars are then converted to carbon dioxide and ethanol through the action of yeast, the latter being the primary desired byproduct. It is besides instrumental in leavening the bread besides stimulates the improvement of the flavor of the bread (McGee, 2004; Struyf *et al.*, 2016). There are also proteins whose amounts depend on the kind of the flour used in the bread making process. Though the protein content is small compared to that of starchy foods, it is substantial enough to have nutritional implication. Protein gliadin and glutenin are especially critical due to the formation of a viscoelastic structure that contributes to entrapment of gases during the fermentation and baking processes to give bread its character. The other proteins present in minimal quantities add value to the nutritional quality of the bread because they introduce the missing amino acids (Wikipedia, 2024).

Whole grain breads contain phenolic compounds like ferulic acid and lignan that are believed to possess antioxidant activity. These compounds mainly found in the bran and germ of grains have health enhancing properties as they act as antioxidants by combating free radicals, anti-inflammatory as well as being useful to the body in many ways (Zhou et al., 2007). Short-chain carbohydrates, collectively referred to as FODMAPs (fermentable oligosaccharides, disaccharides, monosaccharides, and polyols), are another notable chemical component of bread. While they enhance the bread's flavor and texture, FODMAPs can cause digestive discomfort in individuals with sensitive gastrointestinal systems. Traditional bread-making methods, which involve longer fermentation times, have been shown to reduce FODMAP levels significantly, making the bread easier to digest (Handwerks Zeitung, 2024; Struyf et al., 2016).

Acrylamide formation is a chemical process that occurs during baking, particularly at high temperatures. This compound, concentrated in the crust, results from the Maillard reaction between amino acids and reducing sugars. While it enhances flavor and color, acrylamide has raised health concerns due to its potential neurotoxic and carcinogenic effects, warranting ongoing research and attention in bread production (Williams, 2005; Wikipedia, 2024).

2.4 NUTRITIONAL SIGNIFICANCE

The nutritional profile of bread is determined by its composition, processing methods, and the incorporation of additional ingredients, making it a versatile food with varying health benefits. Bread is a significant source of carbohydrates, providing the energy necessary for daily activities. Beyond energy, bread also offers essential proteins, dietary fiber, and micronutrients such as iron, zinc, and magnesium. Enriched and fortified bread varieties further enhance these benefits by addressing specific nutritional deficiencies, particularly in regions where malnutrition is prevalent (Aghalari *et al.*, 2022).

Furthermore, the processing of bread significantly influences its nutritional value. Research published in Dewettinck *et al.* (2008) highlights how whole-grain bread, which retains the bran and germ layers, is superior in nutritional content compared to refined white bread. These components are rich in dietary fiber, antioxidants, and essential fatty acids, contributing to better digestion, reduced risk of chronic diseases, and improved cardiovascular health. Fermentation techniques, particularly sourdough fermentation, also play a role in enhancing the bioavailability of nutrients while reducing antinutritional factors like phytic acid.

Alkurd *et al.* (2020) explore the benefits of multi-grain bread, which combines various grains such as oats, barley, and millet. These breads often exhibit higher fiber content, improved protein quality, and a broader array of vitamins and minerals compared to single-grain breads. Their study also notes that multi-grain breads are often marketed for their health benefits, appealing to consumers seeking nutrient-dense and functional foods.

Despite its nutritional potential, consumer perceptions and choices can influence the health value of bread. As Dewettinck *et al.* (2008) explains, darker breads are often perceived as healthier due to their appearance, even if the color comes from additives rather than whole grains. This underscores the importance of clear labeling and public education to promote informed choices.

2.5 BREAD PREPARATION

Bread preparation is a complex process that combines scientific principles and culinary skills to produce a variety of textures, flavors, and forms. It involves several stages, including mixing, fermentation, shaping, and baking, each contributing to the final product's characteristics. The process begins with mixing the ingredients, typically flour, water, yeast, and salt. During this stage, the dough forms as the proteins in the flour, mainly glutenin and gliadin, combine with water to create gluten. The mixing process helps to activate the gluten

network, which provides structure to the dough (Cauvain, 2012). This is an essential step, as the development of a strong gluten network determines the bread's texture and rise.

Next, fermentation occurs. This is when yeast or other leavening agents consume sugars in the dough, releasing carbon dioxide gas and alcohol. The carbon dioxide gas causes the dough to rise, creating air pockets that make the bread light and airy. The fermentation process can vary in length, depending on the type of bread being made. In some cases, a longer fermentation time allows for a more complex flavor profile, as yeast and bacteria work together to break down starches and sugars (Collado-Fernández, 2003). Fermentation can also be controlled by temperature and humidity, as these factors influence yeast activity and, consequently, the dough's rise (Bernstein, 2019). Shaping the dough follows fermentation. After the dough has risen, it is punched down to release excess air, and then it is shaped into loaves or other forms. Proper shaping ensures an even rise during baking and allows the bread to maintain its structure as it bakes.

Baking is the final and most crucial step. The heat from the oven causes the dough to expand further, as the carbon dioxide gas trapped in the dough continues to expand. The proteins and starches in the dough also undergo chemical changes, leading to the formation of the bread's crust and the development of its flavor. The Maillard reaction, a chemical reaction between amino acids and reducing sugars, occurs at high temperatures and is responsible for the golden-brown crust and rich flavor of freshly baked bread (Cauvain, 2012).

2.6 POTASSIUM BROMATE IN BREAD PRODUCTION

2.6.1 ROLE OF POTASSIUM BROMATE IN BREAD PRODUCTION

Potassium bromate plays a pivotal role in bread making due to its ability to enhance dough quality and improve the overall characteristics of the finished product. As a flour improver and oxidizing agent, it has long been valued for contributing to the baking process,

particularly in large-scale commercial production. Potassium bromate plays the following role in bread production:

1. **Enhancing Dough Strength and Elasticity:** One of the primary roles of potassium bromate in bread production is to strengthen the gluten network in dough. This compound oxidizes the sulfhydryl groups in gluten proteins, resulting in stronger disulfide bonds. This process enhances the elasticity and strength of the dough, making it more resistant to tearing during kneading and shaping. According to Shanmugavel *et al.* (2020), this structural reinforcement allows the dough to trap gases more effectively during fermentation, increasing loaf volume and a uniform crumb structure.
2. **Improving Bread Texture and Appearance:** Potassium bromate also plays a critical role in improving bread's texture and visual appeal. It contributes to a softer crumb, a smoother crust, and a whiter appearance through its oxidative effects, which refine the gluten structure and promote better aeration during baking. Abbas *et al.* (2024) highlight that using potassium bromate is particularly advantageous in creating aesthetically pleasing loaves that meet consumer preferences for softness and brightness.
3. **Facilitating Dough Handling and Processing:** In industrial bread production, potassium bromate significantly improves the handling properties of dough. It makes the dough more pliable and less sticky, which is essential for automated mixing, dividing, and shaping processes. Ncheuveu Nkwatoh *et al.* (2023) emphasize that this enhanced workability reduces production downtime and ensures consistent quality across batches. The compound's ability to improve dough stability during proofing and baking also minimizes production losses, making it a preferred additive in commercial settings.

4. Extending Bread Shelf Life: Potassium bromate contributes to the longevity of bread by improving its structural integrity and reducing staling. By reinforcing the gluten network and enhancing moisture retention, it helps maintain the softness and freshness of bread over an extended period. Singh Rana *et al.* (2020) note that this property is particularly beneficial for producers aiming to reduce waste and meet the demands of modern supply chains.
5. Achieving Consistency in Large-Scale Production: In addition to its functional benefits, potassium bromate ensures consistency in bread quality, which is crucial for large-scale production. Its predictable effects on dough properties and baking outcomes allow manufacturers to produce uniform loaves with minimal variability. This consistency is especially important for meeting consumer expectations and maintaining brand reputation.

2.6.2 PREVALENCE IN BREAD PRODUCTION IN NIGERIA

Potassium bromate, a chemical compound widely used as a flour improver, has been a significant topic of concern in Nigeria's bread industry. Despite global regulations discouraging its use due to its potential health risks, studies reveal its continued prevalence in bread making across different regions of Nigeria. This essay examines the extent of potassium bromate usage in bread production and its persistence in the Nigerian baking industry.

Several studies have documented the presence of potassium bromate in bread samples from various parts of Nigeria. Oloyede and Sunmonu (2009) investigated bread samples in Ilorin, Central Nigeria, and confirmed the presence of potassium bromate at concentrations exceeding permissible limits. Their findings highlighted the widespread use of the compound, often linked to its affordability and effectiveness as a dough conditioner.

Similarly, Magomya and Yebpella (2020) analyzed bread and flour samples sold in Jalingo, Northern Nigeria, and discovered significant levels of potassium bromate in many of

the tested products. This study emphasized the lack of strict enforcement of regulations banning the compound, which has allowed its continued use by local bakeries.

Aletan (2020) explored the prevalence of potassium bromate in Lagos, a metropolitan hub in Nigeria. The study revealed that bread samples from both small-scale and large-scale bakeries contained potassium bromate, further underscoring the compound's widespread adoption. Aletan's findings suggested that its use persists due to a combination of economic factors and limited consumer awareness about its potential risks.

Basically, the persistence of potassium bromate in breadmaking in Nigeria is largely attributed to its functional benefits. Bakers favor the compound for its ability to strengthen dough, improve loaf volume, and enhance bread texture and appearance. These benefits are particularly valuable for small-scale bakeries that aim to produce attractive and durable bread products with limited resources (Olusola *et al.*, 2024). Furthermore, potassium bromate's affordability compared to alternative dough improvers makes it a popular choice among bakers in low-resource settings. This economic factor has perpetuated its use, especially in regions where regulatory oversight and enforcement are weak.

Although Nigeria's regulatory bodies, such as the National Agency for Food and Drug Administration and Control (NAFDAC), have banned the use of potassium bromate in bread production, enforcement remains inconsistent. Many bakeries continue to use the compound, particularly in rural and semi-urban areas where regulatory inspections are infrequent. As Olusola *et al.* (2024) noted in their study of bread samples in Ado Ekiti, Southwest Nigeria, the prevalence of potassium bromate reflects gaps in monitoring and compliance mechanisms.

2.7 TOXICITY EFFECT OF POTASSIUM BROMATE

Potassium bromate (KBrO₃), a widely used flour improver in bread production, has been extensively studied for its toxicological effects. Research highlights its acute, chronic,

organ-specific toxicities, and carcinogenic potential. Below is a detailed discussion of these toxicological properties.

2.7.1 ACUTE TOXICITY

Acute toxicity of potassium bromate occurs when it is ingested in large amounts over a short period, leading to severe physiological disturbances. Symptoms of acute exposure include vomiting, diarrhea, abdominal pain, and hematuria (Nkwatoh *et al.*, 2023). In laboratory studies, high doses of potassium bromate have been shown to induce oxidative stress, resulting in cellular damage and organ dysfunction (Yalçin & Çavuşoğlu, 2022). For instance, experiments on Wistar albino rats demonstrated significant alterations in renal and hepatic biomarkers following acute exposure, indicating immediate organ damage (Oseni *et al.*, 2014).

The oxidative properties of potassium bromate disrupt cellular homeostasis by generating reactive oxygen species (ROS), which damage lipids, proteins, and DNA. This mechanism is pivotal in its acute toxic effects, as observed in both animal studies and reported cases of human poisoning. Without timely intervention, acute exposure can lead to life-threatening complications, including renal failure.

2.7.2 CHRONIC TOXICITY

Chronic exposure to potassium bromate, even at low doses, poses significant health risks due to its cumulative effects. Prolonged ingestion, often from regularly consuming contaminated bread, can lead to persistent oxidative stress, inflammation, and progressive organ damage. Studies have shown that chronic exposure disrupts enzymatic functions and causes long-term damage to the kidneys, liver, and cardiovascular system (Kurokawa *et al.*, 1990).

Yalçın and Çavuşoğlu (2022) observed that prolonged exposure to potassium bromate in rats caused a sustained increase in oxidative markers, suggesting the development of chronic oxidative damage. The chemical's ability to deplete antioxidant defenses, such as glutathione, exacerbates its long-term toxic effects. Chronic exposure has also been linked to nephrotoxicity, hepatotoxicity, and systemic toxicity in both humans and animals.

2.7.3 ORGAN-SPECIFIC TOXICITY

Potassium bromate exhibits a strong affinity for specific organs, particularly the kidneys, liver, and gastrointestinal tract. Nephrotoxicity is one of the most prominent effects, as potassium bromate targets renal tissues, causing glomerular and tubular damage. Kurokawa *et al.* (1990) demonstrated severe renal toxicity in animal models, characterized by proteinuria, hematuria, and renal dysfunction.

Hepatotoxicity is another major concern, with studies reporting oxidative damage to liver cells and disruptions in metabolic enzyme activities (Oseni *et al.*, 2014). Gastrointestinal toxicity, including mucosal irritation and ulceration, is commonly reported in cases of acute and chronic exposure. Additionally, potassium bromate's ROS-generating properties exacerbate organ-specific toxicity, leading to cumulative damage over time (Starek & Starek-Świechowicz, 2016).

2.7.4 CARCINOGENICITY

Potassium bromate is classified as a potential human carcinogen by the International Agency for Research on Cancer (IARC). Its carcinogenicity is linked to its ability to induce DNA damage through oxidative stress. Kurokawa *et al.* (1990) reported renal cell tumors in animal models exposed to potassium bromate, confirming its carcinogenic potential in the kidneys.

Beyond nephrocarcinogenic effects, potassium bromate has been implicated in inducing tumors in other organs, such as the thyroid and peritoneum. Research by Conley

(2023) emphasized that over five decades of studies have consistently demonstrated its genotoxic effects, including the formation of DNA adducts and chromosomal aberrations. These findings highlight the compound's significant risk for inducing cancer, especially with prolonged exposure.

2.8 MECHANISMS OF TOXICITY

Potassium bromate (KBrO_3) is a powerful oxidizing agent widely recognized for its harmful effects on biological systems. The mechanism of its toxicity primarily involves oxidative stress, resulting in significant cellular and molecular damage. Below is an in-depth analysis of the mechanisms through which potassium bromate induces its toxic effects.

2.8.1 Oxidative Stress and Reactive Oxygen Species (ROS) Generation

The primary mechanism of potassium bromate toxicity is the generation of reactive oxygen species (ROS). When potassium bromate enters the body, it undergoes metabolic activation, producing free radicals such as superoxide anion (O_2^-), hydroxyl radical (OH^-), and hydrogen peroxide (H_2O_2) (Yalçın & Çavuşoğlu, 2022). These ROS disrupt cellular homeostasis by oxidizing lipids, proteins, and nucleic acids.

Lipids in the cell membrane are particularly vulnerable to ROS-induced peroxidation. This leads to the breakdown of the membrane's structural integrity, impairing its function and causing cellular leakage. Additionally, ROS-mediated protein oxidation alters enzyme activities, structural proteins, and signaling pathways, further compromising cellular functions (Starek & Starek-Świechowicz, 2016).

2.8.2 DNA Damage

Potassium bromate is highly genotoxic, and one of its most critical toxicological effects is DNA damage. Studies have shown that ROS generated by potassium bromate interact with DNA, resulting in strand breaks, base modifications, and the formation of 8-

hydroxydeoxyguanosine (8-OHdG), a key biomarker of oxidative DNA damage (Kurokawa *et al.*, 1990).

These genotoxic effects are particularly concerning as they contribute to mutagenesis and carcinogenesis. Potassium bromate's ability to cause chromosomal aberrations and sister chromatid exchanges further underscores its impact on genetic material. In vitro studies have demonstrated that cells exposed to potassium bromate exhibit significantly higher rates of micronucleus formation, a sign of chromosomal instability.

2.8.3 Mitochondrial Dysfunction

Mitochondria are a major target of potassium bromate-induced toxicity. The compound disrupts mitochondrial function by impairing the electron transport chain, leading to excessive production of ROS. This not only exacerbates oxidative stress but also reduces ATP production, which is critical for cellular energy metabolism (Oseni *et al.*, 2014).

Mitochondrial dysfunction caused by potassium bromate can trigger apoptosis, or programmed cell death, through intrinsic pathways. The release of cytochrome c from damaged mitochondria activates caspases, leading to the systematic dismantling of cellular components. This process is observed in kidney and liver cells, which are particularly susceptible to potassium bromate toxicity.

2.8.4 Disruption of Antioxidant Defense Systems

Potassium bromate depletes the cellular antioxidant defense systems, further amplifying its toxic effects. Glutathione (GSH), a major intracellular antioxidant, is particularly targeted by potassium bromate. The compound oxidizes GSH into glutathione disulfide (GSSG), reducing the cell's ability to neutralize ROS (Nkwatoh *et al.*, 2023).

Enzymatic antioxidants such as superoxide dismutase (SOD) and catalase are also inhibited by potassium bromate. This inhibition disrupts the cellular redox balance, leaving

cells vulnerable to oxidative damage. The cumulative effect of impaired antioxidant defenses and elevated ROS levels creates a vicious cycle of oxidative stress.

2.8.5 Cellular Signaling Pathway Alterations

Potassium bromate interferes with critical cellular signaling pathways involved in growth, proliferation, and apoptosis. For example, the compound activates stress-response pathways such as nuclear factor kappa B (NF- κ B) and mitogen-activated protein kinases (MAPKs). While these pathways are initially protective, their chronic activation by potassium bromate leads to inflammation, fibrosis, and cellular apoptosis (Conley, 2023).

Additionally, potassium bromate has been shown to upregulate pro-inflammatory cytokines such as tumor necrosis factor-alpha (TNF- α) and interleukins (IL-1 β , IL-6). These inflammatory mediators exacerbate tissue damage and contribute to chronic toxic effects, particularly in the kidneys and liver.

2.8.6 Organ-Specific Mechanisms

1. Kidneys: The kidneys are the primary site of potassium bromate-induced toxicity due to their role in excretion. Potassium bromate causes renal oxidative stress, tubular necrosis, and glomerular damage. The compound's affinity for renal tissues is attributed to their high metabolic activity and susceptibility to ROS (Kurokawa *et al.*, 1990).
2. Liver: In the liver, potassium bromate disrupts metabolic enzymes and induces lipid peroxidation. This leads to hepatocellular damage and impaired detoxification processes, exacerbating systemic toxicity (Oseni *et al.*, 2014).
3. Gastrointestinal Tract: Potassium bromate causes mucosal irritation and oxidative damage to the gastrointestinal lining. This can lead to ulcers, bleeding, and compromised nutrient absorption.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials

3.1.1 Equipment

The following materials were used throughout the project work.

- Weighed sample
- Distilled water
- Foil paper
- Rubber band
- Cotton wool
- Gloves
- Gallon
- Handkerchief
- Bin bags
- Laboratory coat

3.1.2 EQUIPMENT AND APPARATUS

The following equipment and apparatus were used throughout the project work.

- Transparent bowl
- Electronic sensitive weighing balance
- Petri dishes
- Centrifuge
- Standard volumetric flask
- Spatula

- Glass beaker
- Glass stirrer
- Drying oven (105°C)
- Funnel
- Grinder
- Measuring cylinder
- Refrigerator

3.1.3 Chemicals and Reagents

Promethazine (M.W. 320.88 g mol⁻¹, purity, 99.9%) (Biobmei, China), potassium bromate (M.W. 167.00 g mol⁻¹, purity, 99.7%) (Qualikems Fine Chemical Pvt Ltd, India), starch (Central Drugs House, India), potassium iodide (M.W. 166.00 g/mol, purity, ≥99.0%) (Sigma-Aldrich, USA), hydrochloric acid (purity, 35–38%, [HCl] = 11.81 M, M.W. 36.46 g mol⁻¹, Research Lab, India), distilled water, Agege bread, sardine bread, and cassava bread purchased across Benin City. All reagents used for the study were from standard suppliers and of analytical grade.

3.2 Method

3.2.1 Collection of Samples

Bread samples were obtained from bakeries, open markets, bus stations, and local bread vendors throughout Egor Local Government Area in Benin City Metropolis. In total, 20 distinct bread brands were included in the study. The bread-type products were Nigerian fluffy bread (Agege Bread). This bread are of two different sizes: the small size ranging from 1cm to 15cm, and the large size ranging from 16cm and above. The model of the bread are:

Small size (1-15cm)

- Delight bread
- Deluxe bread

- Obey God bread
- Rejoice bread
- Elixir special loaf
- Heavenly bites
- Osefamen special bread
- Yale bread
- God Abeg bread
- Uniben bread

Large size (16cm and above)

- Nadia special bread
- Our home made bread
- Erald butter bread
- Nourish special
- Efe bread
- Matice bread
- Winners bread

3.2.1 Loaf Types, Sizes, Sample Names, and Producer Recommendations (Small Size)

The table below displays the loaf type, size, producer recommendations, and assigned sample names. NB: these sample names represent selections from 20 different bread brands.

Small size (1-15cm):

Delight bread - Sample 1

Deluxe bread - Sample 2

Obey God bread - Sample 3

Rejoice bread – Sample 4

Elixir special loaf - Sample 5

Heavenly bites – Sample 6

Yale bread - Sample 7

Table 3.1 Selected Bread samples for small sized loaf

| Sample | Loaf size | Type of Loaf | Producers specification |
|---------------|------------------|---------------------|--------------------------------|
| 1 | Small | Not sliced | Bromate Free |
| 2 | Small | Not sliced | Bromate Free |
| 3 | Small | Not sliced | Bromate Free |
| 4 | Small | Not sliced | Bromate Free |
| 5 | Small | Not sliced | Bromate Free |
| 6 | Small | Not sliced | Bromate Free |
| 7 | Small | Not sliced | Bromate Free |

3.2.2 Loaf Types, Sizes, Sample Names, and Producer Recommendations (Large Size).

The table below displays the loaf type, size, producer recommendations, and assigned sample names. NB: These sample names represent selections from 20 different bread brands.

Large size (16cm and above)

Nadia special bread - Sample 8

Our home made bread - Sample 9

Erald butter bread – Sample 10

Nourish special - Sample 11

Efe bread - Sample 12

Matice bread - Sample 13

Winners bread - Sample 14

Table 3.2 Selected Bread samples for Large sized bread

| Sample | Loaf size | Type of Loaf | Producers specification |
|-----------|--------------|-------------------|-------------------------|
| 8 | Large | Not sliced | Bromate Free |
| 9 | Large | Not sliced | Bromate Free |
| 10 | Large | Not sliced | Bromate Free |
| 11 | Large | Not Sliced | Bromate Free |
| 12 | Large | Not Sliced | Bromate Free |
| 13 | Large | Not Sliced | Bromate Free |
| 14 | Large | Not Sliced | Bromate Free |

3.3 Preparation of Reagents

3.3.1 Preparations of 0.5% Potassium Iodide Solution

A 0.5% potassium iodide (KI) solution in 2 M hydrochloric acid (HCl) was prepared by dissolving 0.5 g of potassium iodide (Sigma-Aldrich, USA) in 100 mL of pre-prepared 0.1 M HCl in a volumetric flask. The solution was stirred to ensure complete dissolution and mixed thoroughly for uniformity (Smith, 2020). Smith, J., 2020. Laboratory Procedures for Solution Preparation. 2nd ed. New York: Academic Press.

3.3.2 Preparations of Hydrochloric Acid Solution

5M of Hydrochloric acid (HCl) solution was formed by adding 36.5 moles of concentrated HCl to 200 ml of distilled water in a 250 ml volumetric flask (v/v). (where v/v is volume per volume). This is then called solution A. Following that, a separate 2M of Hydrochloric acid solution was formed by dissolving 80ml of solution A up to 200 ml in a 200 ml volumetric flask using distilled water.

3.4 Qualitative Analysis of Potassium Bromate

Bread samples are placed in petri dishes and moistened with distilled water. Then they are well compressed. A 5.0 cm³ portion of freshly prepared 0.5% potassium iodide solution in 0.1 N hydrochloric acid was then sprinkled to various sample. A blue black color change was noted and observed for 5 minutes (Dagari *et al.*, 2022).

3.5 Quantitative Analysis of Potassium Bromate

The process of estimating the intensity of Potassium Bromate in bread was quantitatively done following a slight modification of the existing techniques (El Ati-Hellal *et al.*, 2018). To each of 5mL of the prepared bread filtrate, 0.5 mL of promethazine solution of 0.01M concentration and 100 μ L of 12M HCL was added. The presence of KBrO₃ was

evidenced by the colour change from colourless to pink. The absorption spectrum of promethazine was determined using a double beam spectrophotometer – Cecil CE - 72000 (Cecil Instruments Ltd, UK), identifying the λ_{max} at 515 nm. The absorbances of the mixtures were then measured at 515 nm after shaking. The standard curve for KBrO_3 was prepared with different concentrations of standard solutions with spiking factors at 0, 5, 10, 15, 20, 25, 30, 35, 40, and 45 $\mu\text{g/ml}$ and made from % stock solution and the curve obtained is shown in fig 3. 0.5 mL of freshly prepared promethazine solution of 0.01 M and 100 μL of HCl 12M were mixed to each sample, and absorbance was measured at 515 nm. These absorbances were plotted against the corresponding concentrations, and the KBrO_3 concentration in each sample was determined

CHAPTER FOUR

RESULTS

4.1 Qualitative Analysis of Potassium Bromate in Bread Samples

The results from the qualitative analysis of potassium bromate in bread samples is summarized in the table 4.1 and 4.2. In general, there are presence of potassium bromate in those bread samples tested

Table 4.1 Qualitative Analysis of Potassium Bromate in bread samples (Small size)

| Sample | KBrO ₃ (mg/kg) |
|--------|---------------------------|
| 1 | No Colour Change |
| 2 | Blue black |
| 3 | Blue black |
| 4 | Blue black |
| 5 | Blue black |
| 6 | Blue black |
| 7 | Blue black |

Table 4.2 Qualitative Analysis of Potassium Bromate in bread samples (Large size)

| Sample | KBrO ₃ (mg/kg) |
|--------|---------------------------|
| 8 | No Colour Change |
| 9 | Blue black |
| 10 | Blue black |

| | |
|----|------------|
| 11 | Blue black |
| 12 | Blue black |
| 13 | Blue black |
| 14 | Blue black |

4.2 Qualitative Analysis of Potassium Bromate in Bread Samples

The results from the quantitative analysis of potassium bromate in bread samples is summarized in the table 4. In general, there are significant amount of potassium bromate in those bread samples tested with Sample C being the highest(0.06mg/kg).

Table 4.3 Quantitative Analysis of Potassium Bromate in bread samples (Small sized)

| Sample | KBrO ₃ (mg/kg) |
|--------|---------------------------|
| 1 | 0.01 |
| 2 | 0.01 |
| 3 | 0.02 |
| 4 | 0.03 |
| 5 | 0.03 |
| 6 | 0.04 |
| 7 | 0.04 |

Table 4.4 Quantitative Analysis of Potassium Bromate in bread samples (Large sized)

| Sample | KBrO₃ (mg/kg) |
|---------------|---------------------------------|
| 8 | 0.01 |
| 9 | 0.03 |
| 10 | 0.02 |
| 11 | 0.03 |
| 12 | 0.04 |
| 13 | 0.03 |
| 14 | 0.04 |

CHAPTER FIVE

DISCUSSION AND CONCLUSION

5.1 DISCUSSION

Food safety is a major global concern, particularly in developing countries where regulatory enforcement may be inconsistent. Bread, being a staple food consumed daily by millions, must meet stringent safety and quality standards to ensure public health. One of the most concerning food additives used in bread production is potassium bromate, a flour improver that enhances dough elasticity and volume. Despite its functional benefits in baking, potassium bromate has been classified as a potential carcinogen by the International Agency for Research on Cancer (IARC), and its use in food has been banned in several countries, including Nigeria. However, studies have shown that some bakeries continue to use this additive, often without consumer knowledge.

The presence of potassium bromate in bread poses significant health risks, including oxidative stress, kidney damage, and carcinogenicity. Consequently, regulatory bodies such as the National Agency for Food and Drug Administration and Control (NAFDAC) have imposed strict guidelines prohibiting its use in food production. However, compliance remains a challenge, particularly among small and unregulated bakeries.

The qualitative analysis of potassium bromate in bread samples, as summarized in Table 4.2 and 4.3, demonstrated varied results among different brands. Sample 1 and Sample 8 showed no color change, indicating the absence of potassium bromate. However, samples 2 through 7 and Sample 9 through 14 exhibited a blue-black coloration, confirming the presence of potassium bromate. These findings suggest that despite the manufacturers' claims of being "bromate-free," several bread samples contained the banned additive. This discrepancy highlights the need for stricter regulatory enforcement and quality control in the local bread industry. Comparing these results with previous studies, it is evident that potassium

bromate is still being used by some bakeries, likely due to its ability to improve dough elasticity and bread volume. This aligns with the findings by Adepoju *et al.* (2020), who reported similar occurrences in various local government areas in Nigeria, indicating a widespread issue.

The quantitative analysis results (Table 4.3 and 4.4) further validated the qualitative findings by providing specific concentrations of potassium bromate in the bread samples. The lowest detected concentration is 0.01 mg/kg found in Sample 1,2 and 8, while the highest concentration is 0.04 mg/kg found in sample 6, 7, 12 and 14. Other samples contained potassium bromate levels ranging from 0.02 mg/kg to 0.03 mg/kg. These levels are concerning, considering that the World Health Organization (WHO) and the National Agency for Food and Drug Administration and Control (NAFDAC) have declared any detectable amount of potassium bromate in bread as unsafe.

The presence of potassium bromate, even in small quantities, poses significant health risks. Studies have demonstrated its association with oxidative stress, nephrotoxicity, and carcinogenesis (Nwaogu *et al.*, 2015). Prolonged consumption of potassium-bromate-contaminated bread could lead to serious health complications, including kidney damage and cancer. The highest concentration found in Sample C suggests a deliberate use of the additive by certain bakeries, underscoring the need for consumer awareness and stringent penalties for violators.

The findings of this study emphasize the urgent need for stronger regulatory frameworks and consistent monitoring of bread production in Egor Local Government. While many bakeries label their products as "bromate-free," the presence of potassium bromate in multiple samples suggests false labeling or inadequate quality control measures. These findings reinforce previous reports by Odetunde *et al.* (2018), who highlighted regulatory lapses in food safety enforcement across Nigeria.

5.2 CONCLUSION

This study has demonstrated that despite regulatory prohibitions, potassium bromate is still present in some unsliced bread samples from Egor Local Government. The qualitative and quantitative analyses confirmed the presence of the additive in most samples, with concentrations varying among brands. These findings underscore the need for stricter enforcement of food safety regulations, increased public awareness, and the promotion of safer baking practices to mitigate the health risks associated with potassium bromate consumption.

Future research should focus on a broader survey encompassing different Local Govt. Area and incorporate more advanced analytical techniques for enhanced detection accuracy. Additionally, policy reforms aimed at increasing penalties for non-compliance and encouraging the use of alternative dough improvers could play a crucial role in eliminating potassium bromate from the food supply chain.

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