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Ban on the Use of Potassium Bromate in Nigeria: A Review on Bread Bakers' Compliance with Regulations

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ABSTRACT: Bread is one of the basic and popular foods consumed by the majority of the Nigerians irrespective of their ethnic or socioeconomic status. Potassium bromate ($KBrO_3$) is well known bread enhancer. Because of its negative health effects it has been banned in Nigeria and other countries. This paper aims to reviews studies on the use of $KBrO_3$ in bread to ascertain the safety of the bread products and to also evaluate bakers' compliance with specified regulations. The paper also assesses the possible reasons for the use of $KBrO_3$ by the bread bakers (intentional or unintentional?) as well as addressed what regulatory bodies need to do to improve the bakers' compliance. Fourty seven (47) articles were evaluated and 95.74% of them reported the presence of potassium bromate in the bread samples analysed, which suggests that use of Potassium bromate in bread production in Nigeria is very common and breads sold in Nigeria are unsafe for human consumption. This high usage may be attributed to factors such as bromine in wheat flour, adulterated improvers or due to use of brominated flour. Also, economic gain, high cost of ingredients and poor enlightenment and enforcement may also be contributing factors. Therefore, regulatory bodies need to adopt strategies such as Post-marketing Surveillance (PMS), on the-spot analysis, effective monitoring and enforcement, stringent regulations, and sustained routine and surveillance inspections to at least reduce, if not eliminate, the use of $KBrO_3$ as bread enhancer.

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Bread is a popular food consumed widely amongst all socioeconomic sets in the world (Alli *et al.,* 2013). Bread is a formulation of different ingredients such as wheat flour, sugar, salt, water, improvers and preservatives (Magomya *et al.,* 2013), via different processes comprising milling, mixing, fermenting, molding and baking (Emeje *et al.,* 2010). Bread is a good source of nutrients such as proteins, vitamins (Thiamin-B1, Niacin-B3, Folic acid-B9, Vitamin E and to some extent vitamin A, fibre and complex carbohydrate. It has a low level of fat and cholesterol (Alli *et al.*, 2013). Similarly, bread contains significant amounts of mineral elements such as calcium, magnesium, phosphorous and potassium but others like iodine, iron and sodium are present in minute amounts (Shanmugavel *et al.*, 2019).

Potassium bromate ($KBrO_3$) is a good and well-known bread improver that has been used for many years by different bakers around the world (Nakamura *et al.,* 2006). The use of this compound has been completely banned by different countries across the globe due to its deleterious health effects (Magomya *et al.*, 2013). In addition to bread consumers, bakery workers are also considered to be exposed to this compound via inhalation because of its hepatotoxic and nephrotoxic effects (Oloyede and Sunmonu, 2009). The joint committee of Food and Agricultural Organization (FAO) and the World Health Organization (WHO) has completely banned the use of potassium bromate in bread, due to its long-term toxicity and carcinogenicity (FAO/WHO, 1999). Potassium bromate is a potential class II carcinogen for humans (IARC, 1999) and has also proved to cause severe toxic effects to critical human organs such as kidney, liver, and brain (Ahmad *et al.,* 2015; Ben Saad *et al.,* 2016a&b).

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 death, it was discovered that 92% of bread samples in the country contained potassium bromate (Emeje *et al.*, 2010). Seven (7) different population-based cross-sectional studies alone reported the incidence of CKD in Nigeria to be within 2.5% to 24.3% (Chukwuonye *et al.*, 2018). Both CKD and CLD have enormous financial burdens on the families of subjects (Ulasi and Ijoma, 2010; Chukwuonye and Oviasu, 2012). Therefore, it is believed that a good knowledge of the health consequences associated with the use of potassium bromate in food products, particularly bread and other confectionaries, will drastically reduce the incidence of these chronic diseases. It is considered that maintaining good health as well as prevention of diseases is an essential tool for consumers of food, particularly breads and other flour-based products, thus the need for healthier bread products free from potassium bromate or any other banned substances.

Numerous studies conducted after the ban reported high levels of potassium bromate in bread products produced and consumed in Nigeria (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; Lateefat *et al.,* 2022). Consequently, this review evaluates different studies conducted in the country to ascertain the prevalent of use of Potassium bromate and therefore safety of the bread products and to also determine the bakers' compliance with the specified regulations. Furthermore, this paper assesses the possible reasons for the use of potassium bromate by the Nigerian bread bakers (intentional or unintentional?) and also addresses what regulatory bodies need to do to improve the bakers' compliance with a view to considerably decreasing or abstaining from the use of $KBrO_3$ as bread improver.

Chemistry of Potassium Bromate ($KBrO_3$): Potassium bromate is an IUPAC systematic name given to a chemical compound with the formula $KBrO_3$, a relative molecular mass of 167.01 and a density of 3.27g/cm^3 (Finar, 1973). $KBrO_3$ has a considerably high melting point of about 350°C; and decomposes at about 370°C with emission of oxygen gas and toxic fume (Kurokawa *et al.,* 1990). Potassium bromate is a colourless and odourless crystal which is highly soluble in water; and slightly soluble in acetone, diethyl sulfoxide, ethanol, methanol and toluene (IARC, 1986).

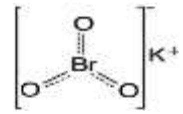

Fig 1: Chemical Structure of Potassium Bromate

Producing countries and Uses of Potassium Bromate ($KBrO_3$): Since 27 years ago, countries such as Argentina, Brazil, China, Germany, India, Israel, Italy, Japan and Spain were the main producers and marketers of potassium bromate (Chemical Information Services, 1995). Potassium bromate ($KBrO_3$) is commonly used for the following purposes:

i. *As flour enhancing agent:* $KBrO_3$ is considered to be a strong oxidizing agent and one of the best and cheapest dough improvers, hence it is commonly used as a flour-enhancing agent in many countries across the globe for the past 90 years (Oloyede and Sunmonu, 2009; Emeje *et al.,* 2010; Shanmugavel *et al.,* 2019). The production and marketing of potassium bromate are geared towards its primary use as a maturing agent for flour and as a dough conditioner despite its detrimental health effects. Potassium bromate has a strong influence on the structure and rheological characteristics of dough because it causes flour maturation and strengthens the gluten network and also helps in the retention of gas and product volume (Ojeka *et al.*, 2006). During bread baking process, potassium bromate is almost completely converted to potassium bromide. Potassium bromate acts mainly in the late dough stage, thereby giving strength and elasticity to the dough during the baking process thus stimulating the rise of bread. These properties make potassium bromate widely used as a flour-enhancing agent in most of the baking industries despite its ban (Ojeka *et al.,* 2006).

ii. *As food additive:* $KBrO_3$ is also used as an additive in beer malting, cheese making, and as an ingredient in fish paste products (Ahmad and Mahmood, 2014).

iii. *Production of pharmaceuticals and cosmetics:* $KBrO_3$ is used in the production of pharmaceuticals and cosmetic products (skin bleaching agents) and also as a component of cold wave hair solutions (Gandikota and MacRitchie, 2005; Alberto and Charles, 2007; Oloyede and Sunmonu, 2009).

iv. *Laboratory reagent:* Besides its use during the fermentation and baking process, $KBrO_3$ is also used as a table reagent and oxidizing agent in the laboratories (Gandikota and MacRitchie, 2005).

Fig 2: Different Uses of Potassium Bromate ($KBrO_3$)

Likewise, $KBrO_3$ is a byproduct of water disinfection produced when waters containing bromide are ozonized (treated with ozone), thus frequently detected in tap and bottled water (Dongmei *et al.*, 2015; Altoom *et al.*, 2018). Liu and Mou (2004) stated that "bromate is one of the most prevalent disinfection by-products of surface water". Ozonation is an effective and efficient means of disinfection due to its ability to clear microbes leading to significant decrease in the level of carcinogenic trihalomethanes (THMs). The Ozonation process introduces ozone in the water which can leads to hydrobromic acid formation with increased content of bromide which subsequently forms brominated organic by-products and bromate (Fiessinger *et al.*, 1985).

Detrimental health effects of potassium bromate: The undesirable and detrimental health effects of potassium bromate were observed and reported since the mid-1980s. Kurokawa *et al.* (1990) reported that $KBrO_3$ poisoning cases in humans are common due to its widespread use and consumption in homes, though the occurrence of such poisoning varied with geographical trends. Most of the $KBrO_3$ poisoning cases in Western countries occurred by accidental ingestion, mostly among children, while in West African countries is more frequently ingested through different foods containing $KBrO_3$ (Kurokawa *et al.*, 1990). Due to this, precautionary measures were adopted by several countries in the world amongst them is its complete prohibition as a dough improver (Omotoso, 2021). Potassium bromate was reported to cause the following deleterious health effects:

i. *Acute and sub-acute toxicity:* Although, the toxic or lethal dose of potassium bromate in humans is not precisely known (Kurokawa *et al.,* 1990). The human lethal dose has been estimated to be 5 to 500mg/kg of body weight (Gradus *et al.*, 1984; Kuwahara *et al.*, 1984) while Watanabe *et al.* (2001) reported human lethal oral doses of 154 to 385mg/kg of body weight. Also, Watanabe *et al.* (2001) reported a serious poisoning at doses of 46 to 92mg/kg body weight. This lethal dose has caused serious symptoms for 15 months old child (Quick *et al.*, 1975). Data from two (2) potassium bromate poisoning cases which occurred in Japan, showed that 9 of the 24 adults died within 3-5 days after ingestion of 5-500mg/kg b.w of $KBrO_3$ (Kuwahara *et al.*, 1984). Also, a severe irreversible sensorineural hearing loss has been reported within 4-16 hours after ingestion of same dose in nearly all of the adults in the 2 cases. Studies conducted for decades by Gosselin *et al.* (1976) revealed that ingestion of 57-133g of 2% solution of potassium bromate caused nausea and vomiting, usually with epigastric and/or abdominal pain; diarrhoea and haematemesis in children of 1.5-3 years of age. Therefore, in the acute stage of poisoning, the main symptoms include vomiting, diarrhoea and abdominal pain. Consequently, manifestations such as oliguria, anuria, deafness, thrombocytopenia, hypotension, vertigo, and depression of the central nervous system followed (Gosselin *et al.*, 1976). Additionally, in both children and adults there have been reported cases of acute renal failure from mild to severe anuric forms (Starek and Starek-Swiechowicz, 2016). Also, Quick *et al.* (1975) and Warshaw *et al.* (1985) reported a strong irritating action of $KBrO_3$ on gastric mucosa.

ii. *Hepatotoxic, neurotoxic, nephrotoxic and mutagenic effects:* Numerous studies shows that long-term exposure to small and high dosages of $KBrO_3$ caused severe damage to the liver tissue architecture through alteration of liver tissues, congestion of the central vein and sinusoidal dilatation as well as liver cells necrosis (Abuelgasim *et al.,* 2008; Akanji *et al.*, 2008; Dimkpa *et al.,* 2013; Olutoyin *et al.*, 2013; Oyewo *et al.*, 2013; Bayomy *et al.*, 2016; Akinola *et al.,* 2020; Hassan *et al.,* 2020). Similarly, $KBrO_3$ can cause vacuolation and sinusoidal dilatation of liver cells with concomitant reduction of antioxidant enzymes and enhancement of xanthine oxidase and lipid peroxidase activities (Khan *et al.,* 2003; Omer *et al.,* 2008). Toxicological studies conducted by Young *et al.* (2001); Ahmad and Mahmood (2012); Saad *et al.* (2017) revealed that $KBrO_3$ affect the neurobehavioral status of different animal models (rats, mice and guinea pigs). A similar study by Chuu *et al.* (2000) showed that $KBrO_3$ prompt injurious effect on auditory brainstem response while it caused oto-neurotoxicity mostly through the peripheral auditory nerve relatively than via the central brainstem intoxication. The nephrotoxic effect caused by $KBrO_3$ is considered to be due to its ability to initiate the production of reactive oxygen species (ROS), lipid peroxidation and 8-hydroxyguanosine modification in renal DNA (Sai *et al.,* 1992; Chipman *et al.,* 1998; Spassova *et al.,* 2015). Two (2) separate studies conducted in Saudi Arabia and Sultanate of Oman by Ajarem *et al.* (2016) and Ali *et al.* (2018) respectively revealed that the amount of ROS induced by $KBrO_3$ significantly surpasses the cellular antioxidant defense capacity, thus leading to manifest nephrotoxicity in humans and animals. The kidney is the main target organs of $KBrO_3$, therefore its toxic effect in humans ascend from acute toxic to renal failure, though the exact mechanism(s) by which $KBrO_3$ induce acute renal toxicity and means to overwhelm the antioxidant defense system its toxic effect using natural products are still unknown (Ben Saad *et al.,* 2016a; Abdel-Latif *et al.,* 2021). Furthermore, it has been proposed by Ballmaier and Epe (1995) that its carcinogenic effect is due to the formation of ROS induced by the compound. Also, Kraus *et al.* (1995) hypothesized that $KBrO_3$ induces tumor formation through DNA strand breaks whereas Kaya and Topaktaş (2007) confirmed the hypothesis by their finding that the compound commonly triggers chromatid and chromosome breaks (chromosomal aberrations). Consequently, Yamaguchi *et al.* (2008) concluded that due to positive results in the Ames test, and chromosome aberration and micronucleus test conducted, $KBrO_3$ has been classified as a genotoxic carcinogen. Several previous studies have proven that potassium bromate is a mutagenic and carcinogenic in different life forms (Abdelraheem and Kambal, 2007; Akintonwa *et al.,* 2010; Elhaddad *et al.,* 2020). The mutagenic effect of $KBrO_3$ is an indication that it has the ability to induce tumor formation through a genotoxic mode of action (Brock *et al.,* 1999). Consequently, the International Agency for Research on Cancer (IARC) categorized potassium bromate as a potential class II carcinogen for humans (IARC, 1999). Several studies have provided evidence that $KBrO_3$ in many consumer products poses mild to severe toxicity to critical organs in humans which include kidneys, liver and brain (Ahmad and Mahmood, 2012; Ahmad *et al.,* 2013; Ahmad *et al.,* 2015; Ben Saad *et al.,* 2016a&b).

iii. *Growth and Reproductive effects:* Although there are scarce studies on the reproductive effect of $KBrO_3$, however, Elsheikh *et al.* (2016) concluded that pre-pubertal exposure of male rats to $KBrO_3$ hinders growth, lowers testicular weight, alters testicular histology as well as impairs spermatogenesis, which predicts infertility or even sterility in the future. The compound binds to the iodine receptors, thus reducing iodine uptake by the thyroid gland and consequently causing iodine deficiency which is the leading factor for growth retardation (Fisher and Bull, 2006). The iodine deficiency induced by $KBrO_3$ affects the biosynthesis of the thyroid hormones and; hence negatively affects the development and function of the gonads (Crockford, 2009). Likewise, Peltola *et al.* (1992); Chlubek (2003) and Sahoo *et al.* (2008) reported that the testis contain sufficient polyunsaturated fatty acids, but insufficient antioxidant defense molecules, thus the iodine deficiency caused by $KBrO_3$ can vulnerably expose the testis to oxidative stress. Additionally, $KBrO_3$ decreases the quality of oocyte due to the OS caused by it (Yamada *et al.,* 2018), and also resulted in the inhibition of mitochondrial spreading throughout the cytoplasm and abnormal mitochondrial aggregation (Nagai *et al.,* 2006; Udagawa *et al.,* 2014). The excess free radicals due to $KBrO_3$ can lead to alterations in the spermatogenic cycle, hypogonadism, reduction of sperm production, alterations of reproductive hormones and degeneration in seminiferous tubules (Khan and Ahmed, 2009). Large amounts of $KBrO_3$ decrease the number of oocytes at the stage of metaphase II and increase abnormal mitochondrial distribution (Yamada *et al.*, 2018).

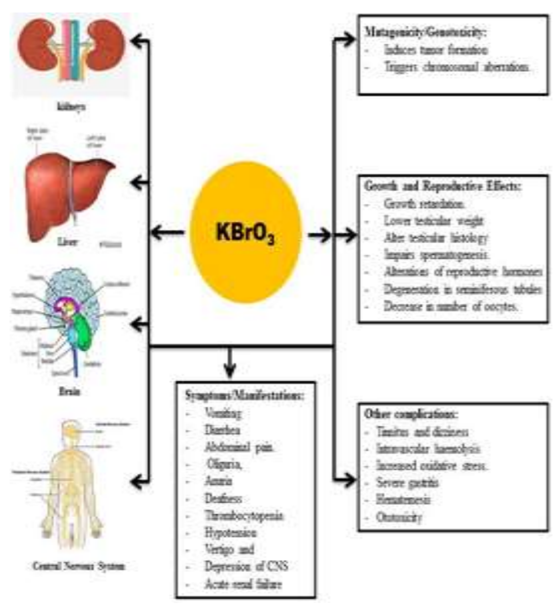

Fig 3: Detrimental health effects of potassium bromate

Effect of Potassium Bromate on Humans (Children and Adults): Consumption of potassium bromate has serious health complications on humans as children and adults. A report of children of 17 months to 6 years who presented with sedation, lethargy and depression of the central nervous system following an inadvertent exposure to about 20mg to 1g/kg b.w of $KBrO_3$ (Shanmugavel *et al.*, 2019). Thereafter, 18 out of the 31 subjects presented with irreversible deafness which occurred within 4 to 16 hours whereas kidney toxicity also occurred, a condition that subsequently led to 26 of them developing with kidney failure. A similar case was also reported in Belgium by De Vriese *et al.* (1997) where a 17-year-old exhibited vomiting, severe abdominal pain and diarrhoea within 30 minutes after ingestion of cold wave neutralizer (containing 10% $KBrO_3$) in her attempt to commit suicide. A few hours after, the victim displayed further complications namely tinnitus and dizziness, with complete loss of hearing. Other complications such as intravascular haemolysis and increased oxidative stress in the renal tubules, leading to kidney failure were confirmed after laboratory examinations.

The consumption of potassium bromate affects not only children but also adults. The first human $KBrO_3$ poisoning case was reported in 1971 by Ohashi *et al.* (1971). In another development, 13 individuals working with a cold wave neutralizer were poisoned with $KBrO_3$. Ohashi *et al.* (1971) reported that the 13 victims manifested with acute renal failure and extended oliguria and subsequently 7 individuals amongst them died due to renal failure, thus resulting in a 54% mortality rate. Furthermore, Kurakowa *et al.* (1990) reported a case of women (professional hairdressers) who consumed potassium bromate to commit suicide and all of them showed vomiting and diarrhoea with abdominal pain, a few hours later oliguria, anuria, deafness, vertigo, hypotension, depression of central nervous system and thrombocytopenia followed. Similarly, Kumar and Pankaj (2012) reported that 9 bakery workers in India presented with abdominal pain, vomiting and diarrhoea following potassium bromate poisoning. All the 9 workers were observed with severe gastritis, leading to hematemesis, and subsequently 24-48h after the intake, acute renal failure ensured. Severe vomiting, abdominal pain and diarrhoea also developed in a 44-year-old man who ingested potassium bromate in an attempt to commit suicide and several hours after, the subject had auditory disturbance and renal failure (Hamada *et al.*, 1990). Human exposure to $KBrO_3$ is associated with ototoxicity, sore throat, nausea, abdominal pain, cough and nephrotoxicity (Uduak, 2019; Magomya *et al.*, 2020). Summarily, nausea, vomiting, abdominal pain and diarrhoea are the characteristic acute symptoms that are displayed shortly after ingestion of $KBrO_3$ whereas acute renal failure changing from mild to severe anuric forms have been reported in both children and adults (IARC, 1999). Oliguria and death from renal failure whereas partial hearing loss and total deafness have also been observed in both children and adults (Quick *et al.*, 1975; Gradus *et al.*, 1984).

Effect of Potassium Bromate on the Environment: Presently no data is available on the bioaccumulation factor of $KBrO_3$ either in plants or animals. But Flury and Papritz (1993) have extensively discussed the bromate ecotoxicity where they reported that aquatic animals such as juveniles of various fish species, crustaceans and flatworms can significantly be affected with a $KBrO_3$ lethal concentration of 31 mg/l - 2258 mg/l. Therefore, from the result of this study scholars such as Hutchinson *et al.* (1997) and Markert (1994) concluded that $KBrO_3$ has low to moderate potential for aquatic toxicity although it also affects sensitive organisms. Furthermore, some industries release $KBrO_3$ into freshwater which is believed to substantially affect sensitive organisms such as fish, freshwater algae and invertebrates and estuarine and marine crustaceans (Shanmugavel *et al.*, 2019). Butler *et al.* (2005); Versteegh *et al.* (1993) also reported that $KBrO_3$ producing industries or industries that use the compound as a raw material contaminate the ground-water that is near them, thereby polluting the environment which will affect many animals including humans.

Effect of Potassium Bromate on the Nutritional Composition of the Bread: Several studies shows that potassium bromate affect the nutritional composition of bread via its strong capacity to destroy vital available vitamins in the bread namely vitamins A1, B1, B2, E and niacin (Magomya *et al.*, 2020). The use of $KBrO_3$ as a bread improver in bread formulation has significant effects on the nutritional value of bread because it degrades essential vitamins (A2, thiamine, riboflavin and niacin) and decreases essential fatty acids (FAO/WHO, 1999; Airaodion *et al.*, 2019; Magomya *et al.*, 2020). Tanaka *et al.* (1980) revealed that potassium bromate directly affects the starch content of the bread via improving the extent of gelatinization, viscosity and swelling of starch. It is widely reported that $KBrO_3$ remove sulfhydryl groups of gluten proteins in dough by oxidizing them into disulfide bonds (Bloksma and Bushuk, 1988). Additionally, Shanmugavel *et al.* (2019) reported that maturating agents such as bromate modify the sulfhydryl groups of protein molecules present in the flour to disulfides in order to enhance the effects of the dough and bread. The presence of potassium bromate in the dough makes the protein less reactive, leading to greater residual protein extractability during the course of bread baking (Kurokawa *et al.*, 1990; Kawasaki *et al.*, 2002). Similarly, Panozzo *et al.* (1994) discovered that addition of $KBrO_3$ affects the extractability of lipids, though not on the general composition of lipids. Potassium bromate does not modify the lipids content of the flour, thus the compound has less effect on the lipids than proteins, but assists in the formation of a protein-lipid complex to enhance bread quality (Panozzo *et al.*, 1994).

Effects of Baking Condition on Potassium Bromate Content in Bread: Studies show that baking temperature has a significant effect on the quantity of potassium bromate in the bread. An experimental study by Abu-Obaid *et al.* (2016) showed that potassium bromate in bread decomposes at a temperature range of 150ºC to 250ºC, unlike in distilled water where the compound decomposes at 350ºC to 400ºC, suggesting that the decomposition of $KBrO_3$ in bread at a low temperature may be due to the metal ions (Fe, Mg, Zn, Mn, Cu and Al) presence in the flour which serve as catalysts.

Another study by Nakamura *et al.* (2006) which measured the effect of processing conditions on the $KBrO_3$ residue in the bread concluded that baking the bread at a temperature greater than 120ºC for more than 30 minutes will not totally degrade the compound, but can moderately degrade it, thereby resulting in lower residual $KBrO_3$. Likewise, Congswell (1997) and Emeje *et al.* (2010) believed that the baking process reduces the toxic $KBrO_3$ to potassium bromide (KBr) which is harmless. But in the event that an extreme quantity of the compound is used during bread formulation or if the bread is not properly baked (baked for a shorter period of time or not at higher temperature), then $KBrO_3$ can be detected in the bread which is toxic (Bushuk and Hlynka, 1960).

Nakamura *et al.* (2006) also reported that a baking lid has a significant effect in reducing the $KBrO_3$ content in the bread than the baking temperature or time, or even changing bread formulation. This is so because the findings of their experiment revealed that no residue of potassium bromate was detected in the bread baked with a baking lid (Pullman-type bread), but it was detected in the open top-type bread (bread baked without a lid) (Nakamura *et al.*, 2006). Shanmugavel *et al.* (2019) explained that their finding may be explained by the proposition that $KBrO_3$ in the upper section of the crust that rises out of the baking pan is related to a decline in the reactive efficiency due to drying of the crust or rapid thermal denaturation of the protein.

Moreover, Himata *et al.* (1997) reported that the baking procedure and flour sample have a significant effect on the quantity of $KBrO_3$ in the bread. However, if a large amount of $KBrO_3$ is added and is not baked at high temperatures or for a longer time, then a residual amount of the compound will remain in the bread which can be harmful if ingested (Kurokawa *et al.*, 1990). This assertion has been corroborated by a study conducted more than 6 decades ago by Bushuk and Hlynkal (1960) who found 31ppm of $KBrO_3$ in the dough (after about 4 hours of fermentation) out of an initial 40ppm of the compound added. They further reported that the residual bromate content reduced to 21ppm after 5 minutes of baking which also disappeared after additional 10 minutes of baking. Additionally, Ronald (2006) stated that during the baking process, potassium bromate is being converted to bromide which is less harmful. In support of this assertion, Lee and Tkachuk (1960) reported that potassium bromate of 30mg/kg was converted to bromide in bread prepared from the flour after a bulk fermentation process. Several studies concluded that the baking process changes the chemical composition of $KBrO_3$ and makes it a harmless compound (bromide), but if a large amount of it is added and the bread is not baked at a longer time or at high temperature, then a residual amount of $KBrO_3$ will remain in the bread.

Studies conducted on the use of potassium bromate in bread products in Nigeria despite its ban: Nigeria is the most populous country in Africa and 6th in the world with an estimated population of 210,431,790 (Statista, 2022b). The country is divided into six (6) geopolitical zones with an estimated 400 ethnic groups and 450 languages (Okorie *et al.*, 2013). The 6 geopolitical zones are North Central, North East, North West, South East, South-South and South West as shown in Figure 1.

Fig 1: Map of Nigeria Showing Six Geopolitical Zones
Abbreviation: FCT; Federal Capital Territory

Table 1: Analysis of Studies on the Potassium Bromate Content in Bread across States of Six Geopolitical Zones of Nigeria.

G/Zone	State	No. of Bread Samples Tested	Amount of $KBrO_3$ Obtained	No. of Samples Tested Positive	Author(s)
North Central	Benue	11	$1.86x10^{-5}$ - $2.75x10^{-5}$ µg/g	All	Gav *et al.* (2019)
	Kogi	20	0.218 - 0.37 µg/g	All	Suleiman *et al.* (2020)
	Kwara	15	0.43 - 0.64 µg/ml	All	Lateefat *et al.* (2022)
	Nasarawa	14	0.50 - 8.40 µg/g	All	Johnson *et al.* (2013)
	Niger	-	-	-	-
	Plateau	30	0.25 - 4.38 mg/g	All	Ekere *et al.* (2020)
		10	0.00 - 6.18 mg/kg	5	Musa *et al.* (2021)
		9	9.39 - 18.49 mg/kg	All	Ogah *et al.* (2021)
North East	Adamawa	10	ND	ND	Alexander *et al.* (2019)
		10	QA	All	Musa *et al.* (2015)
	Bauchi	-	-	-	-
	Borno	-	-	-	-
	Gombe	-	-	-	-
	Taraba	20	2.51 - 11.52 µg/g	All	Magomya *et al.* (2020)
	Yobe	210	0.33 - 0.75 mg/kg	All	Dagari *et al.* (2022)
North West	Jigawa	-	-	-	-
	Kaduna	5	3.70 - 12.10 µg/g	All	Ojeka *et al.* (2006)
		15	2.46 - 13.60 mg/kg	All	Magomya *et al.* (2013)
		10	18.00 - 45.00 µg/cm^3	All	Olabimtan *et al.* (2014)
	Kano	150	18.00 - 45.00 µg/cm^3	All	Abubakar *et al.* (2017)
	Katsina	20	2.18 - 8.25 µg/g	All	Shuaibu and Ibrahim (2013)
	Kebbi	35	4.829 - 11.77 µg/g	All	Ufuoma *et al.* (2020)
		21	0.02 - 0.78 µg/g	All	Shabanda and Saifullahi (2021)
		5	0.02 - 0.78 µg/g	All	Abba *et al.* (2021)
	Sokoto	15	14.70 - 56.20 mg/g	All	Abubakar *et al.* (2008)
		46	0.033 - 0.674 mg/kg	All	Abduljalil *et al.* (2021)
	Zamfara	-	-	-	-
South East	Abia	-	-	-	-
	Anambra	32	0.27 – 3.78 mg/kg	All	Irogbeyi *et al.* (2019)
		10	5.309 - 9.14 ppm	All	Chike *et al.* (2013)
	Ebonyi	-	-	-	-
	Enugu	23	1.16 - 10.44 µg/ml	All	Emeje *et al.* (2010)
		25	26.00 – 146.00 mg/kg	All	Ozoagu (2014)
		15	2.93 – 3.64 µg/L	All	Nosa *et al.* (2018)
	Imo	-	-	-	-
South South	Akwa Ibom	4	0.108 – 0.38 mg/100g	All	Ekop *et al.* (2008)
		12	0.108 - 0.38 mg/100g	All	Aletan and Okon (2018)
		4	6.66 - 52.19 mg/kg	All	Emmanuel and Ernest (2020)
	Bayelsa	-	-	-	-
	Cross River	-	-	-	-
	Delta	10	0.21 – 0.48 mg/g	3	Isaiah (2014)
		20	1.40 – 5.10 µg/g	5	Kelle (2015)
		15	1.00 - 4.21 µg/g	All	Uwague (2017)
	Edo	-	-	-	-
	Rivers	10	0.12 - 7.28 ± 2.14 mg/kg	All	Obunwo and Konne (2014)
		30	0.025-0.06 mg/Kg (South)* 0.011-0.06 mg/Kg (North)*	All	Naze *et al.* (2018)
		60	0.031 - 0.09 mg/kg	59	Naze *et al.* (2019)
		20	0.022–0.04 mg/l	All	Wordu and Akusu (2020)
South West	Ekiti	-	-	-	-
	Lagos	14	0.05 – 1.99 g/g	All	Aletan (2020)
		30	1.18 - 11.13 mg/kg	All	Dada *et al.* (2017)
	Ogun	1512	0.03 – 2.41 µg/g	All	Oyefuga *et al.* (2012)
		12	8.67 - 58.28 µg/g	All	Abiodun *et al.* (2015)
		50	3.23 - 6.29 µg/g	All	Ogunyemi *et al.* (2020
	Ondo	10	1.053 – 1.172 µg/g	All	Akpambang and Onifade (2020)
	Osun	5	ND	ND	Ore (2021)
	Oyo	10	0.02 - 9.33 ppm	All	Olufemi *et al.* (2021)
		30	1.24 - 9.31 µg/g	All	Airaodion *et al.* (2019)
Federal Capital Territory (FCT)		20	3.6 - 9.2 µg/g	All	Alli *et al.* (2013)
		26	1.01 - 12.66 µg/g	All	Emeje *et al.* (2015)

*KEY: $KBrO_3$: Potassium bromate; -: No available data as at the time of compilation; ND: Not detected; QA: Qualitative analysis was conducted; *: the study was conducted in 2 different locations of Port Harcourt (South and North), thus 2 different results were reported.*

Bread is one of the basic foods consumed widely among all ethnic and socioeconomic groups in Nigeria due to its affordability (Alli *et al.,* 2013); therefore bakeries are sited all over the country to meet the demands of the populace. No exact or documented data is available either from government or non-governmental organizations on the actual number of bakeries in the country. Available statistics show that the value of the Nigerian baked goods market amounted to almost N203 million as of 2021 (Statista, 2022b). In 2003, Nigeria's apex drug and food regulatory agency; the National Agency for Food and Drug Administration and Control (NAFDAC) banned the use of $KBrO_3$ in bread due to its deleterious health effects (NAFDAC, 2003). Since then, several studies had been conducted across the 6 geopolitical zones including FCT to ascertain the safety of the products and to also determine the bakers' compliance with the specified Agency's regulations (particularly the ban). Despite the ban on the use of $KBrO_3$, many studies conducted across the nation detected a high level of the compound in the bread products produced and consumed in the country (Emeje *et al.,* 2015; Dada *et al.,* 2016; Uduak, 2019; Uwah and Ikwebe, 2020). These studies are summarized and presented in Table 1 based on the six (6) geopolitical zones of the country and Federal Capital Territory (FCT). Our findings showed that numerous studies on potassium bromate content in bread were conducted in twenty-five (25) states and FCT using different methods. These methods included spectrophotometry, Congo red oxidation, Redox titration, Mohr's methods, HPLC, AAS, crystal violet method, AOAC's method and the Iodometric titration method. The 25 states represent 69.44% of the total number of states in the country where studies are being carried out. A total of Forty-seven (47) different studies (majority quantitative) were reported across the country which were compiled and presented in Table 1. All the analysed studies were conducted within year 2006 (3 years after the ban) to 2022, which conceivably showed that Nigerian bread bakers are still using the compound despite the ban. In Rivers, four (4) independent studies were reported while in other 7 states it was reported by at least 3 different researchers in diverse locations of the states. In all the studies conducted only 2 studies (4.25%) have not reported the presence of potassium bromate in their samples. Similarly, Forty-five (45) studies (95.74% of the total studies) conducted reported the presence of potassium bromate in the bread samples analysed. A unique study by Oyefuga *et al.* (2012) showed the presence of potassium bromate in the entire 1,512 bread samples analysed. This is a unique among all the studies conducted due to the large sample size and long period of sampling and analysis. In the study, six (6) geographically distributed bakeries were selected in a particular local government area while 6 bread samples were randomly selected per bakery on daily basis for six weeks (42 days).

Studies on the potassium bromate content in bread ingredients: Several studies were conducted to evaluate the presence of potassium bromate in bread ingredients particularly wheat flour, yeast and brands of bread improvers. Our findings show that few studies were conducted on potassium bromate contents in the bread ingredients, despite the high level of $KBrO_3$ in bread products reported in many studies.

Table 2: Analysis of Studies on the Potassium Bromate Content in Wheat Flour and Improvers in Some Nigerian States.

State	No. of Samples Analysed	Conc. of $KBrO_3$ in Flour Samples	Conc. of $KBrO_3$ in Bread Samples	No. of Samples Tested Positive	Author(s)
Akwa	4	0.05 - 0.27 mg/100g	0.11 – 0.38 mg/100g	All	Ekop *et al.* (2008)
Ibom	4	0.11 - 0.27 mg/100g	0.11 - 0.38 mg/100g	All	Aletan and Okon (2018)
Anambra	12	0.17 - 0.87 mg/kg	0.27 – 3.78 mg/kg	All	Irogbeyi *et al.* (2019)
Nasarawa	4	0.83 - 1.42 μg/g	0.50 - 8.40 μg/g	All	Johnson *et al.* (2013)
Ogun	12	3.15 - 14.59 μg/g	8.67 - 58.28 μg/g	All	Abiodun *et al.* (2015)
Sokoto	5	0.36 - 0.533 mg/kg	0.03 - 0.67mg/kg	All	Abduljalil *et al.* (2021)
Taraba	4	2.94 - 6.86 μg/g	2.51 - 11.52μg/g	All	Magomya *et al.* (2020)

KEY: $KBrO_3$: Potassium bromate.

The majority of the reported studies analyzed bread products only; however, few of them analyzed other raw materials. Studies by Ekop *et al.* (2008); Abiodun *et al.* (2015); Aletan and Okon (2018); Irogbeyi *et al.* (2019); Magomya *et al.* (2020) and Abduljalil *et al.* (2021) are among the few that analyzed the level of potassium bromate in wheat flour and bread improvers. Their findings indicate the presence of potassium bromate in all wheat flour and bread improvers analyzed. These studies were conducted in five (5) states of the country and are presented in Table 2. The studies analyzed the content of potassium bromate in wheat flour in addition to the bread products and the results showed that the concentration of potassium bromate in wheat flour is lower than in bread products, despite the effect of temperature on the compound as reported by Abu-Obaid *et al.* (2016). This may signify the possible addition of potassium bromate during the formulation which may increase the content of the compound in the finished products. A more recent study carried out by Abduljalil *et al.* (2021) discovered a high concentration of $KBrO_3$ in five (5) different bread improvers used by bread bakers in Sokoto State. This study is unique because as it is the only available study that analyzed other brands of bread improvers beside potassium bromate itself. Being potassium bromate as the best and cheapest flour-enhancing agent (dough improver) amongst others, it may be possible that the manufacturers of such improvers may use the compound in disguise for bakers' satisfaction, and to garner high patronage of their products. It may also be of economic benefits to them, since the compound ($KBrO_3$) is cheaper.

The use of potassium bromate by Nigerian bread bakers: intentional or unintentional?: The high potassium bromate content in bread products reported by numerous studies conducted across the federation may be due to the following factors if not intentionally added by the Nigerian bakers:

i. *Naturally Occurring bromine in flour:* Many foods including wheat flour have a naturally occurring concentration of bromine in a range between 1-10mg/kg which in some foods may substantially be more. The naturally occurring bromine (Br^-) in wheat flour was estimated to be within 2.4 to 7.7mg/kg (Bushway *et al.,* 1998). Bromine is dissolved in water and converted to bromate (Atkins, 1993). This may be the reason why the joint FAO/WHO Committee on food additives temporarily accepted the level of $KBrO_3$ in flour to be within 0 to 60mg/kg with a view that bread products prepared from processed flour may contain minute residue of potassium bromate (FAO/WHO, 1999). Later the joint committee of FAO/WHO stated that the acceptable limit of $KBrO_3$ in flour was withdrawn due to the long-term toxicity and carcinogenicity of the compound. Therefore, many studies recommended that the concentration of $KBrO_3$ obtained in wheat flour may not be necessarily indicated that the flour was intentionally brominated by the producers. Furthermore, it has been reported that gaseous germicides are usually used for wheat cultivation in order to increase the tenability of the wheat. Thus such a germicide when exposed to gas is considered to be highly poisonous to fungi. One of the most commonly used germicides for this purpose is methylene and ethylene dibromine where traces amounts may be found in the wheat flour and bread (Das, 1969). Therefore, Das (1969) reported that the bromine content of the bread may be from the gassed germicides wheat flour containing more bromine residue or due to the natural bromine of the flour or to that of salt used. Additionally, Das (1969) further reported that washing does not remove the high content of bromine added by the gassing. Despite this, all studies reviewed reported a low level of $KBrO_3$ in wheat flour than in bread products, though a significant decrease is expected in the baked bread due to the effect of temperature, pH and period of fermentation on the compound. This may signify that potassium bromate was intentionally added during the bread formulation process.

ii. *Other adulterated improvers:* Although, many brands of bread improvers are produced and marketed as an alternative to potassium bromate, these improvers had not been subjected to safety studies particularly to ascertain their purity if not adulterated with potassium bromate. An exception to this is a study conducted by Abduljalil *et al.* (2021) which evaluated the potassium bromate content in five (5) brands of bread improvers produced and packaged by different manufacturers. The study revealed the presence of a high concentration of potassium bromate in the entire brands of improvers analyzed. All the studies that evaluated the level of potassium bromate in wheat flour reported a low level of the compound in flour than in bread products, despite the effect of the baking condition such as temperature, pH and period of fermentation on $KBrO_3$. This is an indication that other bread ingredients like improvers may be adulterated with potassium bromate by their respective manufacturers for economic gain if not deliberately added by the bakers during bread preparation for cost-effectiveness.

iii. *Brominated flour:* Different types of food additives are used by flour millers during the milling process. A good number of reports have revealed the use of flour improvers during the flour milling process which enhances the nutritive value and attractiveness of the flour and consequently the overall quality of bread (Aboaba and Bakare, 2001). Aboaba and Bakare, (2001) stated that these additives range from vitamins to bleaching and maturing agents which amongst which were potassium bromate, chlorine oxide, ascorbic acid and benzyl peroxide. Some wheat flours are enriched with oxidizing improvers such as potassium bromate and ascorbic acid in order to stimulate the development of gluten in the dough and this type of flour provides dependable results (making the dough stronger and elastic) required by the majority of bakers. The use of $KBrO_3$ among flour millers is becoming common all over the world due to its low-price and its ability to oxidize sulphydryl groups of the gluten protein of the flour into disulphide bridges, thereby becoming less extensible and highly elastic such that it can retain the carbon dioxide gas produced by the yeast (Johnson *et al.,* 2013). The report showed that some flours are brominated in order to make bread rise in the oven, increasing the volume of a loaf and its texture so as to attract high patronage from the bakers whose demands are to produce products that are pleasing to the public (Nakamura *et al.,* 2006; Emeje *et al.,* 2010). Aboaba and Bakare (2001) reported that potassium bromate is normally diluted with other chemicals such as magnesium carbonate or calcium sulphate to make a 0.20g/kg concentration in the flour. Addition of potassium bromate to newly milled flour increases its shelf life (Ogah *et al.*, 2021), its flavour, colour, texture, appearance and stability of the flour and dough (Freer, 1999). Both Ndoni (2009) and Emeje *et al.* (2010) reported that the majority of flour milling industries in Nigeria include bromate during the milling process in order to improve the quality of their products so as to get high patronage from bakers. No doubt the above factors may contribute to the presence of potassium bromate in bread products, although all the studies carried out on the determination of the compound in bread and wheat flour revealed a high concentration of $KBrO_3$ in bread than in wheat flour which may justify the compound is intentionally added by the bakers. Nigeria bread bakers have a dubious ways of including potassium bromate into their bread formulation. These ways include crushing of potassium bromate tablet into powder for easy mixing and homogeneity with wheat flour or simple dissolution in water.

The bread bakers may intentionally add potassium bromate due to the following factors:

i. *Economic gain:* Potassium bromate ($KBrO_3$) is a strong oxidizing agent, generally used to make the bread alluring to the consumers (Dada *et al.,* 2017) and more lucrative to the bakers (Uwah and Ikwebe, 2020). The use of potassium bromate reduces the fermentation period; hence baked bread can be obtained in a shorter period than if not used. Potassium bromate is considered to be inexpensive and readily available compared to other additives; hence using it will significantly reduce the cost of bread production. The use of $KBrO_3$ gives a superior end product, makes the bread to be stronger, and increases its texture as well as its volume (Gandikota and MacRitchie, 2005). This will no doubt attract the consumers which will consequently increase the profit and the general turnover because the more the quantity, the more pleasing is the bread to the buyers. Recently, Mahmud *et al.* (2021) confirmed that bakeries and confectionaries were using $KBrO_3$ in their products for economic benefit, this may be the reason why 92% of Nigerian bread samples contained potassium bromate as reported by Emeje *et al.* (2010). The continued usage of potassium bromate by the baker was attributed to its cheapness.

ii. *High Cost of Ingredients:* High cost of bread ingredients can make most bakers opt for low-cost ingredients such as potassium bromate as alternatives. Though there is a high demand for bread in Nigeria, the majority of the country's population are in extreme poverty, therefore cannot afford to purchase bread at high prices, this created an enabling environment for the bakers to use the substandard ingredient to lower the production cost which in turn will increase their profit. This condition also created a supporting base to which many inferior and local bakeries prosper, who are not properly enlightened with the health hazard of banned ingredients like potassium bromate.

iii. *Poor enlightenment and enforcement:* Many bakers are not fully informed on the health consequence of potassium bromate. Despite the fact that researchers periodically evaluate the bakers' compliance level but their findings have been disturbing which may be attributed to ignorance. The Nigerian illiteracy rate was estimated to be around 62.02% in 2018 (Statista, 2022a) and this can significantly contribute to the inappropriate use of the compound by the bakers without knowing its hazardous effects. Poor enforcement of the stipulated regulation by the concerned regulatory bodies can also contribute to the continued use of the compound by the bakers.

What do regulatory bodies need to do?: In Nigeria, the National Agency for Food and Drug Administration and Control (NAFDAC) is the Agency saddled with the responsibility of regulating all food-related products including bread by section 5 and 30 of the National Agency for Food and Drug Administration and Control Act Cap NI laws of the Federation of Nigeria (LFN) 2004 (NAFDAC, 2022a). The Agency has the sole mandate of ensuring bread products and other confectionaries are produced under Good Hygienic Practice (GHP) and using standard and approved ingredients. The formerly Food and Drug Administration (FDA) now NAFDAC was established by Decree No. 15 of 1993 as amended by Decree 19 of 1999 and presently Act Cap N1 Laws of the Federation of Nigeria, 2004 as an Agency under the Federal Ministry of Health. In 1993, the Agency banned the use of potassium bromate in bread and is violation of decree 20 of 1999 and NAFDAC Decree 15 of 1993 (Akunyili, 2004) and requested the support of all Nigerians especially bread bakers to desist from use of $KBrO_3$ as bread enhancer. Akunyili (2004) also reported that in addition to the ban, the Agency stipulated stringent regulations and penalties on the use of the compound. In spite of the Agency's ban and regulations, yet available information on the Agency's revised 2019 tariff showed no specific administrative penalty for the use of potassium bromate, unlike other offences and violations (NAFDAC, 2019a). In 2017 NAFDAC introduced an international activity code named “Opson” which is an INTERPOL-EUROPOL platform for fighting counterfeit food and beverages (NAFDAC, 2017). But since when the OPSON VI activity was launched in Abuja and Lagos on 17th March, 2017 and 21st March, 2017 respectively, but no available details to prove the commencement and effectiveness of the activity in other states of the country. This activity (OPSON) if properly and effectively coordinated will drastically reduce the importation of potassium bromate. Furthermore, NAFDAC need to introduce a mechanism to checkmate the bakers’ compliance with a view to prevent the Nigerian populace against the toxic effects of potassium bromate. The USFDA had recently launched a food compliance programs which offers instructions and guidelines for their staff to evaluate bakers’ compliance with the laws specified by FDA (USFDA, 2022). The USFDA also established the Food Safety Modernization Act, aimed at preventing food related problem before they happen. This FDA’s Act was introduced to identify food hazards that requires urgent address or minimized through various food sampling for gathering data and information. Therefore, NAFDAC need to introduce and meritoriously coordinate similar programs and regulations in order to specifically evaluate and monitor the bakers’ compliance. This is because, years after the ban on the use of potassium bromate, but available data showed that Nigerian bakers have not complied with the ban. Therefore, the following grey areas if properly addressed by the Agency will drastically reduce if not eradicate the use of $KBrO_3$ as bread improver by the Nigerian bakers.

i. *Post-Marketing Surveillance (PMS):* Post-marketing surveillance is a series of activities conducted by regulatory bodies for the evaluation and collection of information regarding food and drugs after they have been approved for use in a population (Douglas, 2019). Also the PMS helps to ensure that foods and drugs are safe and well-performing and to certify that actions are commenced if their risk outweighs the benefits (WHO, 2021). The post-marketing surveillance otherwise called post-market surveillance will help in monitoring the safety of not only bread production but including its ingredients after they have been released on the market for consumers. In Nigeria, the post-marketing surveillance of food product is overseen by NAFDAC which placed a suitable PMS system to effectively monitor the quality and safety of products and directed all producers of food products (bread inclusive) to comply with their standard requirements to ensure quality food items are sold in the country (NAFDAC, 2019b). Although the Agency has adopted the PMS system in foods, there is a need for effective and efficient utilization of the system particularly on bread products and their ingredients because the system seems to be more active on drugs and medical devices. This will enable the Agency to evaluate the safety of bread and other ingredients particularly flours and improvers at a market level which will guarantee the actual contents of the products. Additionally, the Agency should mandate the manufacturers of bread and its enhancers as well as wheat flour and other ingredients to provide a robust system to receive a feedback from consumers on their products on possible health effects.

ii. *On-the-Spot Analysis:* This is a simple qualitative analysis technique for determining the presence of potassium bromate in bread and its ingredients. At the course of post-marketing surveillance, there is need for NAFDAC to adopt on the-spot-analysis of bread and its ingredients which will ascertain the actual formulation of the products. An instant systematic, subjective and semi-quantitative method of analysis should be established and sustained by NAFDAC in order to evaluate the bread products and ingredients in relation to the standard specified by the Agency. This analysis is to serve as a preliminary qualitative test which is considered simple that can be done at the spot and requires simple analytical reagents. This method involves addition of 2ml of 0.01M promethazine and 0.6ml of 12M hydrochloric acid on a portion of bread sample where a pink colour change indicate the presence of $KBrO_3$ as reported by Alli *et al.* (2013). This method is scientifically effective and its adoption will mandate the bakers to fully comply with the Agency’s regulation, if they believed that their products released in the markets are being properly and effectively monitored and evaluated. Therefore, with the bakers’ dubious means of adding the compound into bread formulation, on-the-spot analysis of bread will help the Agency to evaluate the bakers’ compliance which will ultimately guarantee wholesome bread products for human consumption.

iii. *Effective Monitoring and Enforcement:* There is a need for the National Agency for Foods, Drugs Administration and Control (NAFDAC) and Standards Organization of Nigeria (SON) to ensure effective monitoring of bakeries in order to ascertain their compliance with the Agencies’ stipulated standards of Good Manufacturing Practice (GMP), Good Hygienic Practice (GHP) and Hazard Analysis Critical Control Points (HACCP) guidelines and requirements. Effective *impromptu* monitoring and enforcement of the Agencies’ regulations will significantly stop the use of banned ingredients like potassium bromate by bread bakers and flour millers.

iv. *Stringent regulation:* NAFDAC is solely responsible for regulating and controlling the manufacture, sale and use of foods products and to conduct appropriate tests and ensuring compliance with the standard specification for effective control of the quality of food as enshrined by the Agency's law (Food and Drug Act Cap F. 32 LFN) (NAFDAC, 2022b). Furthermore, the Agency is mandated to establish relevant quality assurance systems, including certification of the production sites and of the regulated products as provided by Food and Drug Act Cap NI LFN as contained under functions and power of the Agency (part II; item c) (NAFDAC, 2022a). Therefore, there is need for the Agency to establish stringent regulation for the production and marketing of bread products and their basic ingredients particularly flour, and bread improvers so as to ascertain their compliance with banned additives.

v. *Sustained Routine and Surveillance inspections:* There is a strong need for relevant regulatory bodies in Nigeria to establish a mechanism for effective and efficient regular and *impromptu* inspections of both registered and unregistered bakeries. This is to enable investigative inspections and prompt responses to consumer complaints and alerts.

Conclusion: Several studies have reported high levels of the compound in bread products despite the ban by NAFDAC. These studies cut across twenty-five (25) states of the federation and FCT. A total of 47 studies were conducted from 2006 to date (3 years after its ban), which means continued usage of the compound. Also, six (6) studies analyzed the level of potassium bromate in wheat flour and bread improvers and their results are positive. This indicates chronic exposure of the populace to $KBrO_3$ and its toxic effects.

REFERENCES

Abdel-Latif, AS; Abu-Risha, SE; Bakr, SM; El-Kholy, WM; El-Sawi, MR. (2021). Potassium bromate-induced nephrotoxicity and potential curative role of metformin loaded on gold nanoparticles. *Sc. Prog.*, 104(3):, 368504211033703.

Abdelraheem, M; Kambal, M. (2007). The Mutagenic Effect of Potassium Bromate (KBrO3) on Drosophila melanogaster, thesis accessed at https://www.researchgate.net/publication/259106445_The_Mutagenic_Effect_of_Potassium_Bromate_KBrO3_on_Drosophila_melanogaster on 6th August, 2022.

Abduljalil, MM; Abubakar, MG; Lawal, SS; Yaissa, AF. (2021). Quantitative evaluation of potassium bromate and some heavy metals in selected bread samples produced in Sokoto State, Nigeria, *Int. J. Food Sci. Nutr.*, 6(4): 99-107.

Abiodun, AA; Michael, AI; Samson, O; Usman, TD; Olusola, OA; John, OO; Babatunde, AO. (2015). Potassium bromate content and some other attributes of selected commercial wheat flour and bread samples in Odeda Local Government, Abeokuta, Ogun State, *Nig. J. Nutr. Sci.*, 36 (1): 67-76

Aboaba, OO; Bakare, KO. (2001). Effect of incorporation of potassium bromate in commercial wheat flour on the proximate composition, storage stability and consumer acceptability of bread, *Biosci. Res. Comm.*, 13(2):1-5.

Abubakar, AI; Ishaq, SA; Yunusa, I; Rabiu, HD; Hassan, KS. (2017). Potassium bromate content of some baked breads sold in Kano Metropolis, Nigeria, *Nig. J. Nutr. Sci.*, 38(1):1-6.

Abubakar, MG, Abbas AY, Faseesin BA. (2008). Potassium bromate content of Bread produced in Sokoto metropolis, *J. of Basic and App. Sci.* 16(2):183-186.

Abuelgasim, AI; Omer, R; Elmahdi, B. (2008). Serrobiochemical Effects of Potassium Bromate on Wistar AlbinoRats. *Am. J. Food Tech.* 3: 303-309.

Abu-Obaid, A. , AbuHasan, S; Shraydeh, B. (2016) Determination and Degradation of Potassium Bromate Content in Dough and Bread Samples Due to the Presence of Metals. *Am. J. Analyt. Chem.* 7, 487-493.

Adebiyi, F; Ore, O; Ojile, F. (2022). Evaluation of potentially toxic elements and bromate levels in bread commonly consumed in Nigeria for human health risk assessment. *J. Trace Elem. Med. & Biol.* 2:1-6.

Ahmad MK; Khan AA; Ali SN; Mahmood R. (2015). Chemoprotective effect of taurine on potassium bromate-induced DNA damage, DNA-protein cross-linking and oxidative stress in rat intestine. *PLoS One.* 10(3): e0119137.

Ahmad MK; Khan AA; Mahmood R. (2013). Taurine ameliorates potassium bromate-induced kidney damage in rats. *Amino Acids;* 45:1109–1121.

Ahmad, MK; Mahmood, R. (2016). Protective effect of taurine against potassium bromate-induced hemoglobin oxidation, oxidative stress, and impairment of antioxidant defense system in blood. *Envir. Toxicol.* 31(3), 304–313.

Ahmad, MK; Mahmood, R. (2012). "Oral administration of potassium bromate, a major water disinfection by-product, induces oxidative stress and impairs the antioxidant power of rat blood," *Chemosphere*, 87(7):750–756.

Airaodion AI, Ewa O, Ogbuagu EO, Ogbuagu U, Agunbiade A, Oloruntoba A.(2019). Evaluation of Potassium Bromate in Bread in Ibadan Metropolis : Fifteen Years after Ban in Nigeria. *Asian Food Sci J.* 2019; 7(4):1–7.

Ajarem, J; Altoom, NG; Allam, AA. (2016). Oral administration of potassium bromate induces neurobehavioral changes, alters cerebral neurotransmitters level and impairs brain tissue of swiss mice. *Behav. Brain Funct.* 12(1): 14.

Akanji, MA; Nafiu, MO; Yakubu, MT. (2008). Enzyme Activitiesand Histopathology of Selected Tissues in Rats Treated withPotassium bromate. *Afr. J. Biom. Res.* 11: 87-95.

Akinola, BK; Olawuyi, TS; Ogunmokunwa, AE. (2020). The Protective Effects of Telfairia Occidentalis on Potassium Bromate Induced Hepatotoxicity in Adult Wistar Rats. *Afr. J. Biol. Sci.* 2(3): 51-61.

Akintonwa, A; Awodele, O; Emeka, P. (2010). The mutagenic potentials of potassium bromate and some commonly used food additives. *Afr J Biotech,* 6(8): 1004-1006.

Akunyili D.N. (2004). Vanguard Media Limited Online; Medical Nigeria, Potassium bromate in Bread – What are the implications? Sensitisation and Interactive workshop for flour millers and bakers.

Akpambang, VOE; Onifade, AP. (2020). Trace Metals Contamination in Bread Ingredients and Bread from Bakeries in Nigeria. *Asian J. Appl. Chem. Res.* 5(2), 26-37.

Alberto, P; Charles, M. (2007). Chapter 96 - Halogens (Bromine, Iodine, and Chlorine Compounds), Editor(s): MICHAEL W. SHANNON, STEPHEN W. BORRON, MICHAEL J. BURNS, Haddad and Winchester's Clinical Management of Poisoning and Drug Overdose (Fourth Edition), W.B. Saunders, Pages 1385-1397.

Aletan, U; Okon, JJO. (2018). Investigation of Potassium bromate and Anti-Nutrient Contents of Flour and Bread in Ikot Ekpene Metropolis, *Inter. J. Basic Sc. Tech.* 4(3):77-80.

Aletan, UI. (2020). Potassium Bromate Content of Bread Samples in Lagos City. *Nig. J. of Pharm. and Applied Sci. Res.* 8(2): 33-36.

Alexander, P; Stephen, E; Irimiya, H. (2019). Quality Assessment of Bread Sold in Gombi Local Government Area, Adamawa State, Nigeria. *Food Sc. Quality Man.* 85, 48-54.

Ali, BH; Za'abi, MA; Karaca, T; Suleimani, YA; Balushi, K; Manoj, P; Ashique, M; Nemmar, A. (2018). Potassium bromate-induced kidney damage in rats and the effect of gum acacia thereon. *Am. J. transl. res*. 10(1): 126–137.

Alli, L. A; Nwegbu, MM; Inyang, BI; Nwachukwu, KC; John OO; Olufunke, O; Mustapha, AJ; Ganiyu AA; Sani, OI; Ernest, AO. (2013): Determination of Potassium Bromate content in Selected Bread Samples in Gwagwalada, Abuja-Nigeria, *Int. J. of H. & Nut.* 4(1): 15-20.

Altoom, NG; Ajarem, J; Allam, AA; Maodaa, SN; Abdel-Maksoud, MA. (2018). Deleterious effects of potassium bromate administration on renal and hepatic tissues of Swiss mice, *Saudi J. Biol. Sci.* 25(2):278-284.

Atkins, D.P. (1993). Potassium bromate in bread. Index to MAFF UK Food surveillance Information sheets. No. 2.

Ballmaier, D; Epe, B. (1995) Oxidative DNA damage induced by potassium bromate under cell-free conditions and in mammalian cells, *Carcinogenesis* 16:335–342.

Bayomy, NA; Soliman, GM; Abdelaziz, EZ. (2016). Effect of Potassium Bromate on the Liver of Adult Male Albino Rat and A Possible Protective Role of Vitamin C: Histological, Immunohistochemical, and Biochemical Study. *Anatomical record (Hoboken, N.J.)*, 299(9):1256–1269.

Ben, SH; Driss, D; Ellouz, CS. (2016). Vanillin mitigates potassium bromate-induced molecular, biochemical and histopathological changes in the kidney of adult mice. *Chem. Biol. Interact.* 252: 102–113.

Ben Saad, H; Driss, D; Ben Amara, I. (2016). “Altered hepatic mRNA expression of immune response-associated DNA damage in mice liver induced by potassium bromate: protective role of vanillin,” *Env. Toxicol.* 31(12):1796–1807.

Bloksma AH; Bushuk W. (1988). Rheology and chemistry of dough. In:Pomeranz Y (ed) Wheat, 3rd edn. *Am. Ass. of Cereal Chemists, St Paul,* pp 131-217.

Brock, KH; Collard, DD; Zucker. RM. (1999) Is genotoxicity a potential mode of action for the carcinogenicity of bromate. Presented at GEMS Meeting, Research Triangle Park, NC, accessed at https://cfpub.epa.gov/si/si_public_record_Report.cfm?Lab=NHEERL&dirEntryID=85231 on 6th August, 2022.

Bushuk, W; Hlynka, I. (1960). Disappearance of Bromate during Baking of Bread. *Cereal Chem.* 37, 573.

Bushway, RJ; Bureau, JI; Gann, DF. (1998). Phytate and cyanide contents of edible mushrooms. *J. Food Sci.* 48, 84-86.

Butler, RAY; Godley, A; Lytton, L; Cartmell, E. (2005). Bromate environmental contamination: review of impact and possible treatment. *Critical reviews in environmental science and technology*, 35(3), 193-217.

Chemical Information Services (1995) Directory of World Chemical Producers 1995/96 Standard Edition, Dallas, TX, p. 587

Chike, SO; Desmond, NO; Chike, CO. (2013). Determination of the Levels and Hepatic Effects of Potassium Bromate in Bread Samples sold in Awka Metropolis, Nigeria, *JSITM:* 2(3):17-21.

Chipman, JK; Davies, JE; Parsons, JL; Nair, J; O'Neill, G; Fawell, JK. (1998). DNA oxidation by potassium bromate; a direct mechanism or linked to lipid peroxidation? *Toxicology*; 126:93–102.

Chlubek, D. (2003). Floride and oxidative stress (editorial), *Fluoride*, 36: 217-228

Chukwuonye, II; Ogah, OS; Anyabolu, EN; Ohagwu, KA; Nwabuko, OC; Onwuchekwa, U; Chukwuonye, ME; Obi, EC; Oviasu, E. (2018). Prevalence of chronic kidney disease in Nigeria: systematic review of population-based studies. *Int. J. Nephrol. Renovasc. Dis.* 22(11):165-172.

Chukwuonye, II; Oviasu E. (2012). The plight of chronic kidney disease patients in Nigeria. *J Dental Med Sci;* 2(2):52–55.

Chuu, JJ; Hsu, CJ; Lin-Shiau, SY. (2000). The detrimental effects of potassium bromate and thioglycolate on auditory brainstem response of Guinea pigs. *Chin. J. Physiol.* 43:91–96.

Congswell, T. (1997). The use of potassium bromate. *Am. Soc. Bakery Eng. Bull.* 240, 5–7.

Crockford, S.J. (2009). Evolutionary roots of iodine and thyroid hormones in cell-cell signaling, *Integr. Comp. Biol.* 49 (2):155-166.

Dada, EO; Akinola, MO; Adewole, OI; Ayobami, PT; Braimoh, BE. (2017). Comparative levels of bromate and metals in bread loaves obtained from corporate and local bakeries in two communities of lagos, nigeria. *FUW Trends Sci. Technol. J.* 2(2):861–4.

Dagari, M; Jafiya, L; Idris, M; Baffa, A. (2022). Determination of potassium bromade in bread samples from Gashua and Nguru communities of Yobe State, Nigeria. *Inter. J. Sci. Tech. Res. Arch.* 3: 058-065.

Das, HA. (1969). The determination of bromine in wheat, Flour and bread by neutronactivation Analysis, RCN Report.

De Vriese, A; Vanholder, R; Lameire, N. (1997). Severe acute renal failure due to bromate intoxication: report of a case and discussion of management guidelines based on a review of the literature. *Nephr. Dialysis Transp.* 12: 204–209.

Dimkpa, U; Ukoha, U; Anyabolu, A; Uchefuna, R; Anikeh, L; Oji, O.J; Besong, E; Emenjo, A. (2013). Hepatotoxic Effects of Potassium Bromate on Adult Wistar Rats. *J. Biol. Agric. & Healthcare.* 3(7):111-116.

Dongmei, L; Zhiwei, W; Qi, Z; Fuyi, C; Yujuan, S; Xiaodong, L. (2015). Drinking water toxicity study of the environmental contaminant--Bromate. *Regulatory toxicology and pharmacology: RTP*, 73(3): 802–810.

Douglas TS. (2019). Chapter 14 - Essentials of Pharmacoepidemiology, Editor(s): Dixon Thomas, Clinical Pharmacy Education, Practice and Research, *Elsevier*, pp.203-214.

Ekere, AS; Ekere, GO. (2020). Determination of potassium bromate in bread samples in Jos metropolis, *Global Sci. J.* 8(4): 768-774.

Ekop, AS; Obot, IB; Ikpatt, EN. (2008). Anti-Nutritional Factors and Potassium Bromate Content in Bread and Flour Samples in Uyo Metropolis, Nigeria", *J. Chem.* 5:1-6.

Elhaddad, NS; Efkerine, EM; Khatab, HA; Eldurssi, IS; Belkasem, EM. (2020). Anti-mutagenic Action of Ruta chalepensis against Rat Sperm Cell Abnormalities-induced by Potassium Bromate. *Ann. Res. & Rev. in Biol*. 35(2), 41-51.

Elsheikh, AS; Fadul, TF; Mohamed-Elkheir, AE; Rahim Gameel, AA. (2016). Effects of potassium bromate on male rat growth and testicular histology, *Asian Pacific J. Repro*. 5:1-16.

Emeje O, Ifiora B, Ezenyi C, Ofoefule S. (2015). Assessment of Bread Safety in Nigeria : One Decade after the Ban on the Use of Potassium Bromate. *J. Food Process Technol.* 6(1):1–4.

Emeje, MO; Ofoefule, SI; Nnaji, AC; Ofoefule, AU; Brown, SA. (2010). Assessment of bread safety in Nigeria: Quantitative determination of potassium bromate and lead, *Afr. J. Food Sc.* 4(6):394- 397

Emmanuel, IU; Ernest, DI. (2020). Trace Metals, Potassium Bromate and Nutritional Potentials in Bread from Bakeries in Uyo, Akwa Ibom State, Nigeria. *Am. J. Appl. Chem.* 8(3):63-73.

FAO/WHO JECFA (1992) Joint Expert Committee on Food Additives: Evaluation of Certain Food Additives and Contaminants. FAO/WHO JECFA, Geneva, 25-33.

FAO/WHO JECFA, (1999). Joint Expert Committee on Food Additives: Evaluation of certain food additives and contaminants, Geneva, pp.25–33.

Fiessinger, F; Rook, JJ; Duguet, JP. (1985) Alternative methods for chlorination. *Sci. Total Environ.* 47: 299-315.

Finar, IL. (1973). Organic Chemistry Vol. I. The fundamental Principles. 6th Edition, *The English Language Book Society and Longman Group Ltd, London* Pp 884-887.

Fisher, J; Bull, RJ. (2006). Development of a rat dosimetry model for bromated, *Toxicology,* 221 (2–3):235-240

Flury, M; Papritz, A. (1993). Bromide in the natural environment: occurrence and toxicity. *J. Env. Quality,* 22(4):747-758.

Freer, OEH. (1999). Food Additives, Chemistry of Food 3rd Edition, Prenctice Hall, New York, 20-41.

Gandikota, S; MacRitchie, F. (2005). Expansion capacity of doughs: methodology and applications. *J. Cereal Sc*. 42: 157-9

Gav, BL; Oloruntoba, SO; Tor, PN; Tsebo, AJ; Usman, Y. (2019). Determination of Bromate Content in Some Selected Bread Produced and Sold Within Makurdi Metropolis, *South As. J.l. Res. Dev.* 1(2):74-80.

Gosselin, RE; Hodge, HC; Smith, RP; Gleason, MN. (1976). Clinical Toxicology of Commercial Products: Acute Poisoning, 4th Ed; *Baltimore, MD, Williams & Wilkins,* p. 66.

Gradus (Ben-Ezer), D; Rhoads, M; Bergstrom, LB; Jordan, SC. (1984). Acute bromate poisoning associated with renal failure and deafness presenting as hemolytic uremic syndrome. *Am. J. Nephrol.* 4:188–191.

Hamada, F; Ohzono, S; Yamada, S; Baba, Y; Tokuda, Y; Yamashita, W; Nakashima, A; Harada, R; Arima, T; Morita, T. (1990). A case of acute potassium bromate intoxication. *Fukuoka Igaku Zasshi,* 81(8):271-6.

Hassan, I; Ebaid, H; Alhazza, IM; Al-Tamimi, J. (2020). The Alleviative Effect of Vitamin B_2 on Potassium Bromate-Induced Hepatotoxicity in Male Rats. *BioMed. Res. Inter*. 2:1-12.

Himata, K; Noda, M; Ando, S; Yamada, Y. (1997). Measurement of bromate in read by high performance liquid chromatography with post-column flow reactor detection. *Food Additives & Contaminants*, 14(8), 809-818.

Hutchinson, TH; Hutchings, MJ; Moore, KW. (1997). A review of the effects of bromate on aquatic organisms and toxicity of bromate to oyster (Crassostrea gigas) embryos. *Ecotoxicology and Environmental Safety,* 38(3), 238-243.

IARC (1986). IARC Monographs on the evaluation of the carcinogenic risk of chemicals to Humans, 40:207-220.

IARC (1999) Working Group on the Evaluation of Carcinogenic Risks to Humans. Some Chemicals that Cause Tumours of the Kidney or Urinary Bladder in Rodents and Some Other Substances. Lyon (FR): International Agency for Research on Cancer; 1999. (IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, No. 73.) Potassium bromate. Available from: https://www.ncbi.nlm.nih.gov/books/NBK402079/

Irogbeyi, LA, Ifeoma, NN; Akuodor, GC; Unekwe, PC; Asika, EC. (2019). Evaluation of Levels of Potassium Bromate and Some Heavy Metals in Bread and Wheat Flour Sold in Aba Metropolis, South Eastern Nigeria. *Asia Pac. J. Med. Toxicol.* 8:71-7.

Isaiah OO. (2014). Trace analysis of bromate chemical in baked Bread from Ughelli urban in Delta State, Nigeria, available at https://www.semanticscholar.org/paper/trace-analysis-of-bromate-chemical-in-baked-bread-%2c-Otalekor/90029f6e449b513d1c229f6af5952d7284afa41e, accessed on 15th August, 2022.

Johnson, OR; Daniel, KD; Iyabo, AG; Oloruntoba, AC. (2013). Analysis of Potassium Bromate and Hydrocyanic Acid Contents of Commonly Consumed Loaves of Bread and Wheat Flour Samples in Karu, Nasarawa State, Nigeria. *IOSR J. of Env. Sc. Tox. & Food Tech.* 6: 42-46.

Kawasaki, Y; Kubota, H; Yomota, C; Maitani, T. (2002). Improved sensitive determination method for bromate in bread, *J. Food Hyg. Soc. Japan,* 43(4): 221-224.

Kaya, FF; Topaktaş, M. (2007). Genotoxic effects of potassium bromate on human peripheral lymphocytes in vitro. *Mutation Research/Genetic Toxicology and Environmental Mutagenesis,* 626(1-2): 48–52.

Kelle, H. (2015). Qualitative and Spectrophotometric Determination of Potassium Bromate In Bread Samples Sold In Asaba, Delta State, *Nigeria. Pakistan J. Chem.* 5. 88-90.

Khan, MR; Ahmed, A. (2009). Protective effects of Digera muricata (L.) Mart. On testis against oxidative stress of carbon tetrachloride in rat. *Food Chem. Toxicol*. 47: 1393-1399.

Khan, N; Sharma, S; Sultan, S. (2003). Nigella sativa (black cumin) ameliorates potassium bromate-induced early events of carcinogenesis-dimension of oxidative stress. *Hum. Exp. Toxicol.* 22: 193-203.17.

Kraus, AL; Munro, IC; Orr, JC; Binder, RL; LeBoeuf, RA; Williams, GM. (1995). Benzoyl peroxide: an integrated human safety assessment for carcinogenicity, *Regul. Toxicol. Pharmacol.* 21: 87–107.

Kumar, S; Pankaj, P. (2012), Accidental Potassium Bromate Poisoning in Nine Adults; case report. *J. Indian Acad. Forensic Med.* 34 (4): 364 – 366.

Kurokawa, Y; Maekawa, A; Takahashi, M; Hayashi, Y. (1990). Toxicity and carcinogenicity of potassium bromate--a new renal carcinogen. *Env. Health Pers.* 87, 309-335.

Kuwahara, T; Ikehara, Y; Kanatsu, K; Doi, T; Nagai, H. (1984) Two cases of potassium bromate poisoning requiring long-term hemodialysis therapy for irreversible tubular damage. *Nephron,* 37: 278-280.

Lateefat, HM, Faith, A; Yusuf, AB; Raimi, OM. (2022). Food for the Stomach Nourishing our Future: Assessment of Potassium Bromate in Local and Packaged Bread Sold in Ilorin Metropolis, *Public H. Open Acc.* 6(1):000197

Lee, CC; Tkachuk, R. (1960). Disappearance of bromate during baking of bread, Cereal *Chem*. 37, 575.

Liu, Y; Mou, S. (2004) Determination of bromate and chlorinated haloacetic acids in bottled drinking water with chromatographic methods. *Chemosphere*, 55: 1253-1258.

Magomya, AM, Yebpella, GG; Udiba, UU; Amos, HS; Latayo, MS. (2013). Potassium Bromate and Heavy Metal Content of Selected Bread Samples Produced in Zaria, Nigeria, *Inter. J. of Sc. & Tec.* 2(2): 232-237

Magomya, AM, Yebpella, GG, Okpaegbe, UC; Nwunuji, PC. (2020). Analysis of Potassium Bromate in Bread and Flour Samples Sold in Jalingo Metropolis, Northern Nigeria, *J. Env. Sc; Tox. & Food Tech.* 14(2):01-05.

Mahmud, SS; Moni, M; Imran, AB; Foyez, T. (2021). Analysis of the suspected cancer-causing potassium bromate additive in bread samples available on the market in and around Dhaka City in Bangladesh. *Food Sci. Nutr.* 24; 9(7):3752-3757.

Markert, B. (1994). The biological system of the elements (BSE) for terrestrial plants (glycophytes). *Science of the Total Environment*, 155(3), 221-228.

Musa, N; Abdullahi, S; Faisal, M.S; Hassan, A; Ambi, A. (2021). Determination of potassium bromate level in ten different bread samples at Jos North, Plateau State, available at https://www.researchgate.net/publication/356536292_determination_of_potassium_bromate_level_in_ten_different_bread_samples_at_jos_north_plateau_state#fullTextFileContent, accessed on 21st August, 2022.

Musa, Y; Alexander, P; Barminas, JT; Ezekiel, WT; Magilli, S. (2015). Physicochemical analysis of bread sold in Mubi town of Adamawa state, *ADSUJSR*, 03(1):110-118.

NAFDAC (2017). NAFDAC enforcement action: International activities, downloaded at https://www.nafdac.gov.ng/, on 3rd November, 2022.

NAFDAC (2019a). NAFDAC 2019 revised tariff, downloaded online at https://www.nafdac.gov.ng/resources/nafdac-tariff/, accessed on 3rd November, 2022.

NAFDAC (2019b). Post-marketing Surveillance On Food, Drug And Other Regulated Products #12191, available at https://www.nafdac.gov.ng/post-marketing-surveillance-on-food-drug-and-other-regulated-products-12191/ accessed on 31st August, 2022.

NAFDAC (2022a). National Agency for Food and Drug Administration and Control Act Cap N.1 LFN 2004, Arrangement of Sections, available online at https://www.nafdac.gov.ng › Files › NAFDAC_Acts, accessed on 3rd November, 2022.

NAFDAC (2022b). NAFDAC Laws, available on https://www.nafdac.gov.ng/about-nafdac/nafdac-laws/, accessed on 3rd November, 2022.

Nagai, S; Mabuchi, T; Hirata S. (2006). Correlation of abnormal mitochondrial distribution in mouse oocytes with reduced developmental competence. *Tohoku J. Exp. Med.* 210:137-144.

Nakamura, MIK; Murakami, T; Himata, K; Hosoya, SEIO; Yamada, YUJI. (2006). Effects of reducing agents and baking conditions on potassium bromateresidues in bread. *Cereal Foods World,* 51(2), 69-73.

Naze, AU, Owhoeke, E; Ekpete, AO. (2019). Determination of Bromate Content of Selected Bread Brands Consumed within Port Harcourt and Its Environs, *Chem. Res. J.* 4(3):86-91

Naze, AU; Epete, OA; Owhoeke, E. (2018). Bromate content in thirty different brands of bread baked in Port Harcourt Metropolis Rivers State, *J. Appl. Sci. Environ. Manage.* 22 (8) 1321 –1324

Ndoni, SA. (2009). "A survey of bromate content in bread sold in Bayelsa state, Nigeria". *J. Res. Bios.* 5(3): 5-8.

Nigeria Data Portal (2006). Nigeria - Population Census – 2006, available at ttps://nigeria.opendataforafrica.org/ifpbxbd/state-population-2006, accessed on 10th August, 2022.

Nosa, TO; Richard, IE; Peter, UA. (2018) "Rapid Method Estimation of Bromate in Serum and Bread Consumed in Enugu, Nigeria". *Acta Sci. Nutr. Health* 2(8):04-12.

Oashi, N; Shiba, T; Kamiya, K; Takamura, T. (1971). Acute renal failure following potassium bromate ('cold wave' neutralizer) poisoning (recovery from prolonged oliguria. *Nihon Hinyokika Gakkai Zasshi.* 62(8):639-46.

Obunwo, CC, Konne, JL. (2014). Measurement of Levels of Potassium Bromate and Some Heavy Metals in Bread Samples Produced in Port Harcourt Metropolis, Nigeria, *Inter. J. Appl. & Nat. Sc. (IJANS),* 3(3): 1-4

Ogah, E; Dodo, JD; Awode, AU; Egah, GO; Ezeme, EC; Ebereonwu, PU. (2021). Determination of potassium bromate concentration in Some bread samples in Jos metropolis, *FUW Trends in Science & Tech J.* 6(2):639 – 642.

Ogunyemi, MO; Akinremi, CA; Akinhanmi, TF; Adewuyi, S. (2020). Development of indicator for on-site detection of bromate in some bread samples in abeokuta metropolis, *J. Chem. Soc. Nig.* 45(4):739-747.

Ohashi, N; Shiba T; Kamiya K; Takamura T. (1971). Acute renal failure following potassium bromate 'cold wave' neutralizer) poisoning (recovery from prolonged oliguria). *Jpn. J. Urol.* 62:639–646.

Ojeka, E; Obidiaku, M; Enukorah, C. (2006). Spectrophotometeric determination of bromate in bread by the oxidation of dyes. *J. Appl. Sci. Env. Man.* 10(3), 43– 46.

Okorie PN, Ademowo GO, Saka Y, Davies E, Okoronkwo C. (2013) Lymphatic Filariasis in Nigeria; Micro-stratification Overlap Mapping (MOM) as aPrerequisite for Cost-Effective Resource Utilization in Control and Surveillance. *PLoS Negl. Trop. Dis.* 7(9): e2416.

Olabimtan, O; Agboni, M; Myek, B. (2014). Effects of Potassium Bromate and Moisture Contents of Some Selected Bread Samples in Zaria, Kaduna State, Nigeria, *Int. J. Modern Chem.* 6(3): 131-136.

Oloyede, OB; Sunmonu, TO. (2009). Potassium bromate content of selected bread samples in Ilorin, Central Nigeria and its effect on some enzymes of rat liver and kidney. *Food & chemical toxicology an international journal published for the British Industrial Biological Research Association*, 47(8), 2067–2070.

Olufemi, L; Okunye, I; Philip, A; Okanlawon, B; Meshach, AM; Ovuakporaye, IW. (2021). Bacteriological examination and potassium bromate analysis of bread samples from selected retail outlets in two locations south west Nigeria, *The Nig. J. pharm*. 55 (2): 71-76.

Olutoyin, O; Onyije, F; Awoniran, P. (2013). Hepatotoxic Effect of Potassium Bromate on the Liver of Wistar Rats. *J. Morphological Sci.* 30. 107-114.

Omer, R; Abuelgasim, A.L; Elmahdi, B. (2008). Effect of Potassium Bromate on Liver and Blood Constituents ofWistar Albino Rats. *Am. J. Food Tech.* 3: 310-314.16.

Omotoso, O. (2021). Assessment of Bread Safety: A Review of Potassium Bromate Level in Breads Sold and Consumed in Nigeria. *Asia Pacific J. Med. Toxicol*. 10(4), 140-144.

Ore, OT. (2021) Heavy Metal Levels and Potassium Bromate Content of Bread Commonly Consumed in Nigeria. *J. Heavy Met. Toxicity Dis.* 5(3):1-6.

Oyefuga, O; Alabi, M; Bisuga, N; Salau, B; Adebiyi, AA, Adedokun, TA. (2012). Comparison of Potassium Bromate ($KBrO_3$) contents in locally consumed wholesome wheat bread in Ikenne Local Government Area of Ogun State, Nigeria. *J. Sci. & Tech.* 2. 55-60.

Oyewo, OO; Onyije, FM; Awoniran, PO. (2013). Hepatotoxic effect of potassium bromate on the liver of wistar rats, *J. Morphol. Sci.* 30(2):107-114.

Ozoagu, CP. (2014). Undergraduate research project submitted to the department of industrial chemistry faculty of natural sciences, available online at https://www.academia.edu/8665713/Analysis_of_Potassium_Bromate_in_Bread, accessed on 11th August, 2022.

Panozzo, JF; Bekes, F; Wrigley, CW; Gupta, RB. (1994). The effects of bromate (0-30 ppm) on the proteins and lipids of dough. *Cereal Chem.* 71, 195-195.

Peltola, V; Huhtaniemi, I; Ahotupa, M. (1992). Antioxidant enzyme activity in the maturing rat testis, *J. Androl.* 13: 450-455.

Quick, CA; Chole, RA; Mauer, SM. (1975) Deafness and renal failure due to potassium bromate poisoning. *Arch. Otolaryngol.* 101, 494–495.

Ronald, R. (2006). "Bromine" *Acu-cell nutrition*; 2, 7.

Saad, H; Kharrat, N; Driss, D; Gargouri, M; Rim, M; Jamoussi, K; Magné, C; Boudawara, T; Chaabouni, S; Zeghal, K; Hakim, AB; Amara, I. (2017). Effects of vanillin on potassium bromate-induced neurotoxicity in adult mice: impact on behavior, oxidative stress, genes expression, inflammation and fatty acid composition. *Archives of Physiology and Bioch.* 123. 1-10.

Sahoo, DK; Roy, A; Bhanja, S; Chainy, GBN. (2008). Hypothyroidism impairs antioxidant defence system and testicular physiology during development and maturation. *Gen. Comp. Endocrinol.* 156: 63-70

Sai, K; Uchiyama, S; Ohno, Y; Hasegawa, R; Kurokawa, Y. (1992). Generation of active oxygen species in vitro by the interaction of potassium bromate with rat kidney cell. *Carcinogenesis*. 13:333–339.

Shabanda, IS; Saifullahi, I. (2021). Human Exposure to Potassium Bromate from Bread Consumption in Aliero, Kebbi State, Nigeria, *J. Inn. Res. in Life Sci.* 3(1): 38-42.

Shanmugavel, V; Komala Santhi, K; Kurup, A.H; Kumar Kalakandan, S; Anandharaj, A; Rawson, A. (2019). Potassium bromate: effects on bread components, health, environment and method of analysis: a review, *Food Chem.* 311; 1-49.

Shuaibu, L; Ibrahim, AY. (2013). Spectrophotometric Determination of Bromate in Breads using Promethazine, *Inter. J. Current Res.*, 5(8):.2236-2238.

Spassova, MA; Miller, DJ; Nikolov, AS. (2015). Kinetic modeling reveals the roles of reactive oxygen species scavenging and DNA repair processes in shaping the dose-response curve of KBrO3-induced DNA damage. *Oxid Med Cell Longev*, 2015:1-12.

Starek, A; Starek-Swiechowicz, B. (2016) Toxicological Properties of Potassium Bromate. *J. Pharm. Reports*, 1: 122.

Statista (2022). Literacy rate in Nigeria in selected years between 1991 and 2018, available at https://www.statista.com/statistics/1268372/literacy-rate-in-nigeria/ accessed on 30th August, 2022.

Statista (2022). Market value of baked goods in Nigeria from 2016 to 2021, available at https://www.statista.com/statistics/856314/nigeria-baked-goods-market-value/ accessed on 10th August, 2022.

Suleiman, SM; Olajide, EJ; Omede, A; Olupinyo, O; Usman, OS; Suleiman, I. (2020). Comparative Assessment of Bromate in Bread in Kogi State, Nigeria, *Chem. Res. J.* 5(2): 67-70.

Tanaka, K; Endo, S; Nagao, S. (1980). Effect of potassium bromate, potassium iodate, and L-ascorbic acid on the consistency of heated dough. *Cereal Chem.* 57(3), 169-174.

Udagawa O; Ishihara T; Maeda, M. (2014). Mitochondrial fission factor Drp1 maintains oocyte quality via dynamic rearrangement of multiple organelles. *Curr. Biol.* 24:2451-2458.

Uduak, A. (2019). Potassium Bromate Content of Bread Samples in Lagos City. *Nig. J. Pharm. Appl. Sci. Res.* 8(2):33–6.

Ufuoma, BS; Aliyu, AT; Daniel, AA; Yusuf, AB; Emmanuel, O; Yahaya, OT. (2020). Estimation of the Potassium Bromate Content in Low and High Price Bread Sold in Birnin Kebbi, *FUW Trends in Sci. Tech. J.* 5(2):417 – 420.

Ulasi, II; Ijoma, CK. (2010). The enormity of chronic kidney disease in Nigeria: the situation in a teaching hospital in South-east Nigeria. *J. Trop. Med.*501957.

USFDA (2022). Compliance & Enforcement (Food), available at https://www.fda.gov/food/compliance-enforcement-food, accessed on 4th November, 2022.

Uwague, A. (2017). Investigation into the Health Danger of Potassium Bromate in Bread Consumed in Sapele Town, Delta State, *Int. J. Modern Eng. Res. (IJMER)*, 7(9): 01–03.

Uwah, EI; Ikwebe, ED. (2020). Trace Metals, Potassium Bromate and Nutritional Potentials in Bread from Bakeries in Uyo, Akwa Ibom State , Nigeria. *Am. J. Appl. Chem.* 8(3):63–73.

Versteegh, JFM; Neele, J; Cleven, RFMJ; Smeenk, JGMM; Westra, R. (1993). Bromide and bromate in drinking and surface water. *RIVM report*, 734301001. RIVM, Bilthoven (in Dutch).

Abba, A; Umar KJ; Umar, SW; Bello YK; Umar A. (2021). Comparison of Potassium bromate Comparison of Potassium bromate (KBrO3) Content in Bread of Nigeria and Niger Republic, *Savanna J. Basic & Appl. Sci*. 3(2): 164-166

Warshaw, BL; Carter, MC; Hymes, LC; Bruner, BS; Rauber, AP. (1985). Bromate poisoning from hair permanent preparations. *Pediatrics*, 76:975-978.

Watanabe, S; Yoshimura, Y; Fukui, T. (2001). Contribution of glutathione peroxidase and nitric oxide to potassium bromate-induced oxidative stress and kidney damage in mice. *J. Health Sci.* 47: 565-570.

WHO (2021). Guidance for post-market surveillance and market surveillance of medical devices, including in vitro diagnostics, available at https://www.who.int/publications/i/item/9789240015319 accessed on 31st August, 2022.

Wordu, GO, Akusu, OM. (2020). Determination of potassium bromate and proximate composition of selected breads sold within Port Harcourt metropolis, *Int. J. Food Sc. & Nutr.* 5(2): 04-08.

Worldometer (2022). Nigeria Population (Live). Available at https://www.worldometers.info/world-population/nigeria-population/ accessed on 10th August, 2022.

Yamada, K; Hiradate, Y; Goto, M; Nishiyama, C; Hara, K; Yoshida, H; Tanemura, K. (2018). Potassium bromate disrupts mitochondrial distribution within murine oocytes during in vitro maturation. *Reprod. Med. Biol.* 17(2):143-148.

Yamaguchi, T; Wei, M; Hagihara, N; Omori, M; Wanibuchi, H; Fukushima, S. (2008). Lack of mutagenic and toxic effects of low dose potassium bromate on kidneys in the Big Blue rat. *Mutation Res.* 652(1), 1–11.

Young, YH; Chuu, JJ; Liu, SH; Lin-Shiau, SY. (2001). Toxic effects of potassium bromate and thioglycolate on vestibule ocular reflex systems of Guinea pigs and humans. *Toxicol. Appl. Pharmacol.* 177:103–111.