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Nutritional content of popular malt drinks produced in Nigeria

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Five popular commercial brands of malt drinks (Maltina, Malta Guinness, Amstel Malt, Hi-Malt and Grand Malt) produced in Nigeria were analyzed for pH, conductivity, turbidity, total dissolved solids, total soluble solids, level of bitterness, reducing sugar, vitamins A and C and minerals. Malt drinks were found to be acidic with pH range of 4.4 - 4.6. Maltina has the highest conductivity of 2.93 mS/cm and a TDS of 1480 mg. Bitterness level ranged from 11 - 13 Bu (Grand Malt) and 15 - 17 Bu (Amstel Malta). The reducing sugar content was found to be high and it ranged from 693.45 - 923.37 mg/dl. Vitamin A content of the drinks were in the range of 40.99 (Grand Malt) – 49.51 mg (Malta Guinness) and Vitamin C ranged from 5.69 (Grand Malt) - 9.97 (Maltina); these values were adequate, meeting Dietary Reference Intakes (DRIs). The content of iron, zinc, cadmium, calcium, copper, chromium, manganese, nickel and lead was negligible, while the content of calcium and sodium was low.

Key words: Malt drinks, minerals, turbidity, conductivity, reducing sugar and dietary reference intakes.

INTRODUCTION

Malt drink is a non-alcoholic beverage obtained from unfermented wort. It is a very common drink in the Caribbean Islands and Latin America, but its consumption in Nigeria has been on the increase. Historically, malt drink was used as food for children and the sick, but has since become a mainstream beverage consumed by people of all ages. More importantly, malt-based drinks have developed a reputation over the centuries for their nutritional value, a message that is attractive for manufacturers to carry across in today's climate of increasing health awareness.

The introduction of the new non-alcoholic malt beverage is yet another example of how the marketplace responds when the public changes its mind. Since their rediscovery a few years ago, non-alcoholic malt beverages and wines have become something of a growth industry. It is not that they threaten the market for "real" beers; these important versions are finding a niche of their own by satisfying "current lifestyle interests" (Miller, 1986). Malt-based soft drink producers have certainly found inventive ways of breathing new life into

old-time brands by updating the products and appealing to new consumer groups. Arguably, the most vibrant strand of growth may lie within the market for non-alcoholic malt beverages and non-alcoholic beer in the Middle East, Muslim populations in the West and some Christian groups that forbid the drinking of alcohol. It was forecasted that sales of non-alcoholic beer alone will increase by 54% in the five-year period to 2011 across Africa and Middle East, while in pioneering markets such as Egypt, per capita consumption will reach 1.8 litres per annum by the end of this period, up from just 0.1 litres in 1997 (Iivonen and Partington, 2007). With smart marketing and possibly the addition of functional ingredients to their products manufacturers of non-alcoholic beer and other malt-based non-alcoholic drinks can simultaneously appeal to all health-conscious consumers in the international market place. In Nigeria, it has now turned out to be a drink preferred in most social gatherings, for health and or religious belief.

The manufacturing process of fermentation for malt-based soft drinks is similar to that used in beer production, with the products containing typically malt, sugar, and hops. Fermentation has not only been useful in terms of preservation, but has helped to add flavour and texture (Murray et al., 1997). However, various processes

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have been developed for Malt production of various qualities. Owades (1992) patented a method for preparing an alcohol-free barley malt-based beverage of reduced caloric content (Owades, 1992). The method consists of adding to a conventionally processed Malta beverage, following boiling, cooling and filtering, but prior to packaging an amylolytic enzyme system. The amylolytic enzyme system converts the maltose and complex carbohydrates (dextrin) present in the beverage extract to simple, sweet-tasting dextrose. Another patent reported a method for the production of substantially non-alcoholic beer by a continuous yeast treatment at a low temperature. In the process, wort, which has been clarified and possibly treated by evaporating and/or with an adsorbing agent, is passed through a packed column reactor containing immobilized yeast at a temperature ranging between the freezing point of wort and 10°C. The yeast is reactivated at 2 - 15°C for 10 - 30 h (Lommi and Ahvenainen, 1997). Recent practice is to cool the wort from 100 - 3°C so as to prevent the survival of micro-organism (Miller, 1995). After super cooling, the wort is fortified with micronutrients to improve the nutritional quality of the drink. Fortification of products has been used extensively as a base for advertisement; however, there is no known standard in Nigeria. As a general rule, it is necessary in order to provide nutritionally approximate amounts of micronutrients without creating excess or imbalance; one portion of the food should not provide too large a portion of the requirements for the target consumers. Nearly all fortified processed foods contain more than one added micronutrient. Dairy products (milk) are often fortified with vitamins A and D only, while other beverages are fortified with many minerals and vitamins (Calvo et al., 2004).

The purpose of this work is to evaluate some physicochemical parameters, the content of nutrients and essential minerals of malt drinks marketed in Nigeria. In order to accomplish this objective, we evaluated the content of sugar, minerals, total dissolved solids (TDS), total soluble solids (TSS), vitamins A and C, turbidity, level of bitterness and pH.

MATERIALS AND METHODS

Sample collection and preparation

Five different commercial brands of locally produced malt drinks were analyzed. A sample of each brand of Malt drink was purchased from three different supermarkets in Port Harcourt, Rivers State, Nigeria. The samples were stored in a refrigerator to reduce the temperature to 18 - 20°C. The Malt drinks were opened, degassed, decolourised by treatment with activated charcoal and filtered; to give clear filtrates used for analyses.

Acid digestion of samples

30 ml of sample was measured into a clean 250 ml dry Pyrex digestion flask. 10 ml concentrated nitric acid was added, followed

by the addition of 3.0 ml perchloric acid. The digestion flask was heated gently until frothing subsided. The sample was then heated to dryness, dissolved in 30 ml distilled water and filter with No. 42 Whatman filter paper. The solution was made up to volume in a 100 ml flask.

Determination of pH

An Orion digital pH / millivolt meter 611 was used to measure the pH after calibration with standard pH tablets of pH 4, 7, and 9.2.

Determination of conductivity

A Thermo Orion was used to obtain conductivity as readout after calibrating the instrument with 0.1N KCl.

Determination of turbidity (Turbidity, 2009)

A Hach 2100N Turbidimeter was used to obtain turbidity as read out after calibration at 0.1 NTU, 20 NTU, 200 NTU, 1000 NTU and 4000 NTU.

Determination of total dissolved solid and total soluble solid (Total suspended solids, 2009)

The samples were analyzed on Hach DR/800 directly with the principle of dispersion of light due to suspension.

Determination of bitterness

To 10 ml degassed sample in 100 ml volumetric flask was added 1.0 ml HCl and 20 ml iso-octane. The flask was stoppered and mechanically agitated for 10 min, allowed to settle and the clear solution (avoid the emulsion) was transferred to a test tube. The test tube was stoppered, kept for 45 min and absorbance measured at 275 nm.

Determination of reducing sugar (Miller, 1959)

The dinitro salicylic acid method was used to estimate reducing sugar. One millilitre of the malt drink was reacted with an alkaline solution of 3,5- dinitro salicylate reagent to give the brown coloured 3-amino-5-nitrosalicylic acid solution and measured at 540 nm. The quantity of reducing sugar was extrapolated from a calibration curve prepared with D-glucose.

Determination of vitamin A (Plummer, 1978)

The Car-Price reaction was used to estimate vitamin A. Ten millilitres of the sample was extracted with chloroform. The extract was treated with a saturated solution of antimony trichloride. The absorbance of the resulting solution was read at 620nm against a reagent blank. The concentration of vitamin A in the sample was deduced from a calibration curve prepared with a standard solution of vitamin A.

Determination of vitamin C (Jayaraman, 1992)

Vitamin C (ascorbic acid) was determined by titration with 2,6-dichlorophenol indophenol. Ten millilitres of each sample was

Table 1. Physicochemical characteristics and nutrients in some selected malt drinks produced in Nigeria.

Parameters	Malta Guinness	Amstel Malta	Maltina	Grand Malt	Hi-Malt	Sample standard deviation
pH (degassed)	4.4 (0.200)	4.6 (0.200)	4.4 (.200)	4.6 (0.200)	4.6 (0.200)	0.110
Cond. (μ S/cm)	1444 (4.000)	1698 (6.928)	2.93mS/cm(0.100)	1999 (1.000)	1567 (1.000)	238.407
Turb. (NTU)	>1000 (0.000)	>1000 (0.000)	>1000 (0.000)	>1000 (0.000)	>1000 (0.000)	0.000
TDS (mg/l)	705 (5.000)	829 (10.000)	1480 (26.458)	985 (1.000)	680 (4.000)	327.369
TSS (mg/l)	>1067 (0.000)	>1067 (0.000)	>1067 (0.000)	898 (1.000)	830 (3.000)	48.08326
Bitterness levels (Bu)	15 - 17	14 - 17	14 - 16	11 - 13	12 - 14	279.307
Sugar (mg/dl)	923.37 (3.000)	693.45 (10.000)	819.65 (4.726)	826.17 (3.990)	718.65 (0.150)	92.455
Vitamin A as B-carotene (mg/dl)	49.51 (3.000)	48.15 (2.000)	48.13 (2.000)	40.99 (0.030)	45.28 (0.020)	3.400
Vitamin C (mg/dl)	9.48 (2.646)	9.95 (1.026)	9.97 (0.020)	5.69 (0.020)	8.33 (0.030)	1.801
Fe (ppm)	0.28 (0.020)	0.15 (0.050)	0.13 (0.010)	0.14 (0.015)	0.11 (0.010)	0.068
Zn (ppm)	0.10 (0.040)	0.10 (0.010)	0.06 (0.020)	0.05 (0.010)	0.05 (0.015)	0.026
Cd (ppm)	0.01 (0.003)	0.01 (0.002)	0.01 (0.002)	0.01 (0.001)	0.01 (0.001)	0
Cu (ppm)	0.01 (0.002)	0.02 (0.006)	0.01 (0.003)	0.01 (0.002)	0.01 (0.002)	0.005
Cr (ppm)	0.01 (0.003)	0.03 (0.006)	0.01 (0.001)	0.01 (0.002)	0.01 (0.001)	0.009
Mn (ppm)	0.01 (0.004)	0.01 (0.001)	0.01 (0.002)	0.01 (0.002)	0.01 (0.002)	0
Ni (ppm)	0.01 (0.002)	0.01 (0.002)	0.01 (0.000)	0.01 (0.002)	0.01 (0.003)	0
Pb (ppm)	0.01 (0.002)	0.01 (0.000)	0.01 (0.001)	0.01 (0.002)	0.01 (0.001)	0
Ca (ppm)	0.28 (0.026)	3.12 (0.120)	262 (5.292)	48.2 (0.200)	65.3 (0.656)	107.852
Na (ppm)	38.0 (2.000)	12.92 (0.600)	27.1 (0.173)	15.8 (0.200)	17.9 (0.300)	10.236

nd = Below detection limit. The detection limit = 0.001 ppm. All samples were done in triplicate. Include the standard deviation for each attribute and each sample. Standard deviation of each attribute is given in bracket and sample's in column.

treated with 0.4% oxalic acid and titrated with 2,6-dichlorophenol indophenol to a faint pink end point. A blank of a standard solution of ascorbic acid was treated similarly. The content of ascorbic acid in the malt drink was then obtained by calculation and results were expressed as mg/100 ml/dl.

Determination of mineral content

The mineral content of each malt drink was obtained as readout by aspirating the acid digest and using the individual metal lamps in an Atomic Absorption Spectrophotometer (Unicam model 860).

RESULTS AND DISCUSSION

Table 1 shows the physicochemical parameters of the various brands of malt drinks analyzed. The malt drinks are quite acidic with pH of 4.4 (Malta Guinness and Maltina) and 4.6 (Amstel, Hi-malt and Grand malt). Their pH is in the range recommended for table wine (816-R01-416, 2001).

Conductivity is the ability of electricity to pass through water, using the impurities contained in the water as the "conductor." When water has lots of impurities, it is more "conductive," however, if water is pure, it is less "conductive," unless it is

polarized (Maurice Shachman, 2010).

Water only conducts electricity when it has impurities in it. Distilled or filtered water is not conductive, but regular tap water that contains minerals is conductive. Hence, malt conducts electricity because it contains minerals and it follows that the malt brand with the highest concentration of minerals will conduct the most. The order of conductivity, which is also the order of TDS in this study is Maltina > Grand malt > Amstel malt > Hi-malt > Malta Guinness. It is not surprising for this trend since conductivity is often used as an estimate of total dissolved solids (TDS)

content of water samples (Maurice Shachman, 2010). The Total Suspended Solids (TSS) is the material trapped on a filter, while that which goes through the filter is called Total Dissolved Solids (TDS). The order of TSS content was Maltina = Malta Guinness = Amstel malt > Grand malt > Hi-malt. The TSS content of Maltina, Malta Guinness and Amstel malt were above the instrument detection limit of 1067 mg/l.

Turbidity is the measure of the cloudiness of water, and the cloudier the water, the greater the turbidity, which is caused by particles in transparent products (Maurice Shachman, 2010). A particle is defined as something with a different refractive index as the carrier product. Some examples of particles are minerals, yeast cells, metals, oil drops in water, milk in water, gas bubbles and aerosols. The turbidity of all the malt drinks was above the detection limit of the instrument at 1000 Ntu, which means that the malt drinks contain high levels of particles in them. The level of bitterness was in the order of Malta Guinness > Amstel malt > Maltina > Hi-malt > Grand malt.

Vitamin A is a fat soluble vitamin, which is essential for normal growth, vision, immune response and cell differentiation (Ezepue, 1995). The concentration order of vitamin A is Malta Guinness > Amstel malt > Maltina > Hi-malt > Grand malt. Vitamin A levels are in the range of 40.99 - 49.51 mg/l and these values are similar to those reported earlier for some unspecified brand of malt drinks, which were in the range between 40.55 and 51.70 µg/dl (Okon and Akpanyung, 2005). The intake of vitamin A recommended by FAO is 750 µg retinol per day for adults; with lactating mothers requiring less (FAO, 1988). Studies have shown that over 34 - 69% of childhood blindness in Nigeria is caused by corneal opacity, which results mainly from an interplay of vitamin A deficiency, measles and harmful traditional eye practices (FAO, 1988; Rabiun and Kyari, 2002). However, vitamin A deficiency which manifests in the eye as xerophthalmia is the dominant problem in these children. The level of vitamin A in the malt drinks of the present study is about 33% of the Daily Required Intakes (DRIs) (Rabiun and Kyari, 2002).

Vitamin C is the enolic form of 3-oxo-L-gulofuranolactone also known as ascorbic acid, L-ascorbic acid, dehydroascorbic acid, the antiscorbutic vitamin, L-xyloascorbic acid and L-threo-hex-2-uronic acidylactone. It is a powerful water-soluble antioxidant that boosts the immune system and helps prevent cancer and heart disease (Rai and Anand, 2008). Vitamin C will be more effective if taken with bioflavonoid, calcium and magnesium. To enhance the antioxidant properties, it will be best to take it with the other antioxidants, as there is strong evidence of synergy between all of them. Yet, this vitamin cannot be manufactured by the body and needs to be ingested.

When there is a shortage of Vitamin C, various problems can arise, although scurvy is the only disease

clinically treated with vitamin C. However, a shortage of vitamin C may result in "pinpoint" haemorrhages under the skin and a tendency to bruise easily, poor wound healing, soft and spongy bleeding gums and loose teeth. Edema (water retention) also happens with a shortage of vitamin C, a lack of energy, poor digestion, painful joints and bronchial infection and colds are also indicative of deficiency. The Dietary Reference Intakes (DRIs) for vitamin C used to be 40 mg (Weber et al., 1996), but now is 60 mg per day - yet this amount will only prevent scurvy (Hirschmann and Raugi, 1999). A recent study suggested that an intake between 200 - 500 mg per day may be most beneficial for healthy people with a recommended upper limit for vitamin C supplements of 2 g/day, while pregnant or lactating women is 75 - 95 mg per day (Iivonen and Partington, 2007). In our study, Grand malt (5.69 mg/dl) has the lowest vitamin C content in the malt drinks, while Amstel (9.97 mg/dl) has the highest. In a previous study, the amounts of vitamin C in the malt drinks were estimated to range between 3.13 and 9.97 mg/dl (Okon and Akpanyung, 2005). Hence, drinking a bottle of 30 cl of Amstel will provide one with about 15% of the DRIs for vitamin C. Producers of malt drinks usually promote and advertise their products as being fortified with nourishments, of which vitamin C is one of them.

The concentration of reducing sugar ranged from 693.45 - 923.37 mg/l. The order of concentration is Malta Guinness > Grand malt > Maltina > Hi-Malt > Amstel malt. Previous report gave the amounts of reducing sugar in unspecified brand of malt drinks that ranged from 603.66 - 943.45 mg/dl (Okon and Akpanyung, 2005). The major sources of sugar in malt drinks are through the enzymatic hydrolysis of the starchy raw materials (saccharification) at the mashtun and the addition of sugar at the wort copper where protein coagulation, deactivation of malt enzymes, sterilization, evaporation of volatiles, formation of flavour, colour complexes and fortification also take place. The added sugar is used to increase fermentable extraction fraction and to sweeten the drink. The accumulative sugar for these malt drinks supplies more than one gram of reducing sugar per standard bottle of 30 cl. This sugar level serves as a source of instant energy for immediate utilization for athletes, convalescents, hypoglycaemia patients and other persons involved in heavy physical activity but could be risky for those on restricted sugar diet and hyperglycaemia patients.

Another important fortificant are minerals, which are inorganic substances that are essential to the functioning of organ systems and our entire body (Ryan-Harshman and Aldoori, 2005). Some of these minerals exist in large amounts in our body such as calcium, while others such as manganese exist in trace amounts but are, nonetheless, critical to our health and well-being (Ryan-Harshman and Aldoori, 2005). If mineral levels are excess in the body, such as sodium, they may facilitate

negative effects in the body. High sodium levels may elevate blood pressure. If mineral levels are inadequate in the body, such as iron, they may facilitate negative effects in the body. Low iron levels in women can produce anaemia (a deficiency in blood iron levels). Anaemia can restrict oxygen and carbon dioxide removal from the cells. Low calcium levels can facilitate irregular muscle contractions, bone density loss, blood clotting and improper brain functioning.

Iron level of the malt drinks ranged between 0.11 and 0.28 mg/dl. The DRIs for iron are 10 mg/day for men and 15 mg/day for women (Institute of Medicine, 2001). Although these values are low, their presence contributes to the daily iron source. Iron is important in many biological processes because it is an ideal oxygen carrier and because it can function as a protein-bound redox element. Iron deficiency is common worldwide and in infants can cause severe neurological deficit (Prasad, 1995).

The concentration of micronutrient zinc was 0.05 (Grand malt and Hi-malt) and 0.10 mg/dl (Amstel malt and Malta Guinness). Zinc is such a critical element in human health of which, a small deficiency is a disaster. Zinc deficiency is characterized by growth retardation, loss of appetite and impaired immune function. In more severe cases, zinc deficiency causes hair loss, diarrhoea, delayed sexual maturation, impotence, hypogonadism in males, and eye and skin lesions (Ryan-Harshman and Aldoori, 2005). The DRIs for zinc is 15 mg for ages 4 and above. Zinc is involved in numerous aspects of cellular metabolism. It is required for the catalytic activity of approximately 100 enzymes and it plays a role in immune function, protein synthesis, wound healing, DNA synthesis, and cell division (Institute of Medicine, 2001; Prasad, 1995). A daily intake of zinc is required to maintain a steady state because the body has no specialized zinc storage system (Ryan-Harshman and Aldoori, 2005; Institute of Medicine, 2001).

Cadmium concentration in all the samples was 0.01 mg and these exceeded the maximum contaminant levels (MCL) of 0.005 mg/L set by US EPA (1985). Cadmium is a non-essential metal and produces only significant adverse health effects.

Copper concentration in the malt drinks ranged from 0.01 - 0.02 mg. This is below the DTIs of 0.1 mg (Institute of Medicine, 2001). Copper is needed for proteins involved in growth, nerve function and energy release (Institute of Medicine, 2001). It is vital for the formation of some important proteins. It is a critical functional component of a number of essential enzymes, known as cuproenzymes. Two copper-containing enzymes, ceruloplasmin (ferroxidase I) and ferroxidase II are involved in iron metabolism (Attieh, 1999). Copper is stored in appreciable amounts in the liver. It also has anti-oxidant properties and involved in the regulation of gene expression.

Chromium concentration in the malt drinks was 0.01 mg except Amstel (0.03 mg). Chromium is involved in

the processes that make glucose available for energy. It is also important for the metabolism of amino acids (the 'building blocks' of proteins) and fats (Institute of Medicine, 2001). Deficiency symptoms include glucose intolerance or insulin resistant hyperglycaemia (excess sugar in the blood), raised serum lipids and weight loss. Studies have shown that chromium helps to lower blood sugar in individuals with type II Diabetes.

Manganese concentration in all the malt drinks was 0.01 mg. Manganese is an actual component of manganese super oxide dismutase enzyme. It is a powerful antioxidant that searches the free radicals in human body and manages to neutralize these damaging particles and prevent any potential danger they may cause. There is actually no recommended dietary allowance for manganese, but normally about 5 mg/day is enough. Deficiency in manganese leads to various health problems, which may include bone malformation, eye and hearing problems, high cholesterol levels, hypertension, infertility, weakness, heart disorders, memory loss, muscle contraction, tremors, seizures and so on (Institute of Medicine, 2001).

Calcium concentration of the malt drinks is in the order Maltina > Hi-malt > Grand malt > Amstel malta > Malta Guinness. Calcium is needed for the formation and maintenance of bones, the development of teeth and healthy gums. It is necessary for blood clotting, stabilizes many body functions and is thought to assist in preventing bowel cancer (Attieh, 1999). It has a natural calming and tranquilizing effect and is necessary for maintaining a regular heartbeat and the transmission of nerve impulses. The required amount include: 1,000 mg/day for people aged 19 - 50 years and 1,200 mg per day for people over the age of 51 years. The maximum level of calcium is 2.5 g/day (Ryan-Harshman and Aldoori, 2005).

Nickel concentration in all the malt drinks was 0.01 mg. Nickel is a trace element, required in minute quantities by the human body. It is found widely in the environment and also in almost all tissues in the human body. Though pre-sent in minute quantities, nickel can accumulate in the kidneys, bones and thyroid gland and cause toxicity. The functions of nickel in the human body are still not very clear. Enzymes containing nickel have not been found, though nickel functions to activate or inhibit enzymes containing other elements (Ryan-Harshman and Aldoori, 2005; Institute of Medicine, 2001).

Lead (Pb) concentration in all the malt drinks was 0.01 mg and this is similar to the result obtained by Adraiano (1984) who reported Pb levels of 0.01 ppm for beverage drink in Canada. Maduabuchi et al. (2006) reported Pb concentrations range of 0.002 - 0.0073 for canned beverages and 0.001 - 0.092 mg/L for non-canned beverages sold in Nigeria (Yates et al., 2003). Lead toxicity causes many sign and symptoms such as abdominal pains, anaemia, anoxia, bone pain, brain damage, convulsion, dizziness, inability to concentrate etc.

The body needs a small amount of sodium to help maintain normal blood pressure and normal function of muscles and nerves. Sodium intake is recommended to be less than 3,000 mg daily. One teaspoon of table salt contains about 2,000 mg of sodium.

Conclusion

The Malt drinks (Maltina, Malta Guinness, Amstel Malt, Hi-Malt and Grand Malt) produced in Nigeria used for this study are acidic, but richly fortified with nutrients (sugar, minerals, vitamin A and vitamin C). However, there is the need to have an acceptable standard of type and form of fortification for all malt producers to follow (reformulate this sentence). However, it is necessary to establish a standard fortificant and concentration for all malt producers to adhere to.

According to the 2005 *Dietary Guidelines for Americans (Dietary Guidelines for Americans, 2005)*, "nutrient needs should be met primarily through consuming foods. Foods provide an array of nutrients and other compounds that may have beneficial effects on health. In certain cases, fortified foods and dietary supplements may be useful sources of one or more nutrients that otherwise might be consumed in less than recommended amounts. However, dietary supplements, while recommended in some cases, cannot replace a healthful diet". Daily multivitamin and mineral supplements containing approved levels of minerals are safe for nearly everyone, but use of supplements should include individual risk assessment.

REFERENCES

- Adraiano D (1984). Trace metals in the terrestrial environment. 1st Edn. Verlag Spiegler, New York pp.19-21.
- Attieh ZK, Mukhopadhyay CK, Seshadri V, Tripoulas NA, Paul L (1999) FoxCeruleoplasmin Ferroxidase Activity Stimulates Cellular Iron Uptake by a Trivalent Cation-specific Transport Mechanism, *J. Biol Chem.*, 274: 1119.
- Calvo MS, Whiting SJ, Barton CN (2004). Vitamin D and health in the 21st century: bone and beyond. *Am. J. Clin. Nutr.*, 80(6): 1710S-1716S
- Dietary Guidelines for Americans (2005). Department of Health and Human Services (HHS) and the Department of Agriculture (USDA). Draft). EPA 600/X-84/190-1, Cincinnati, OH: U.S. Environmental.
- Ezepue UF (1995). Vitamin A deficiency: a causal factor in childhood corneal diseases and blindness in eastern Nigeria. *Niger. J. Ophthal.*, 2(3):35 - 39.
- FAO (1988). Requirements of vitamin A, iron, folate and vitamin B. Report of a joint FAO/WHO expert 12 consultation. FAO, Rome.
- Hirschmann JV, Raugi GJ (1999). Adult scurvy. *J. Am. Acad. Dermatol.*, 41:895-906.
- Iivonen J, Partington PY (2007). Global: Malt-based drinks set for healthy growth, *EuroMonitor Int.*, 28: 11.
- Institute of Medicine (2001). Food and Nutrition Board. Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc. Washington, DC: National Academy Press.
- Jayaraman J (1992). Laboratory manual in Biochemistry. Wiley Eastern Ltd., New York.
- Lommi H, Ahvenainen J (1997). Process for the production of non-alcoholic or low alcohol malt beverage, 5612072.
- Maduabuchi JMU, Nzegwu CN, Adigba EO, Aloke RU, Ezomike CN, Okocha CE, Obi E, Orisakwe OE (2006). Lead and cadmium exposures from canned and non-canned beverages in Nigeria: A public health concern. *Sci. Total Environ.*, 366(2-3): 621-626.
- Maurice SM (2010). The soft drinks companion: a technical handbook for the beverage industry, CRC Press. p. 45.
- Miller D (1995). Siphons, Cold Trub, pH Meters, Jockey Boxes, and Commercial-Scale Wort Chilling Brewing Techniques
- Miller GL. (1959). Use of dinitrosalicylate reagent for determination of reducing sugar. *Annal Chem.*, 31: 427- 431.
- Miller RW (1986) Non-alcoholic beer and wine: How close to the real thing, *FDA consumer*, p. 20.
- Murray CR, Van der Meer WJ (1997). Improvements in production of fermented malt beverages, *Biotechnol. Adv.*, 15(1): 276.
- Okon EU, Akpanyung EO (2005). Nutrients and Antinutrients in Selected Brands of Malt Drinks Produced in Nigeria, *Pak. J. Nutr.*, 4 (5): 352-355.
- Owades JL (1992). Preparation of non-alcoholic malt beverage, United States Patent 5120557.
- Plummer DT (1978). An Introduction to Practical Biochemistry. 2nd (ed.) Tata McGraw-Hill Publishing Co., New Delhi. p. 28.
- Prasad AS (1995). Zinc: an overview. *Nutrition*; 11:93-99. Protection Agency, Environmental Criteria and Assessment Office.
- Rabiu MM, Kyari F (2002). Vitamin A deficiency in Nigeria. *Niger. J. Med.*, 11(1) :6-8.
- Rai B, Anand SC (2008). Serum and Salivary Vitamin C in Periodontal Disease: *Adv. Med. Dent. Sci.*, 2(2): 26.
- Ryan-Harshman M, Aldoori W (2005) Health benefits of selected minerals, *Can. Fam Physician.* 51(5): 673–675.
- Total Suspended Solids (2009). APHA 2540 D.
- Turbidity (2009). APHA – 2130 B.
- US, EPA (1985). Drinking Water Criteria Document for Copper (Final USEPA 816-R01-416 (2001)). The stage 1 disinfectant and disinfection by-products rule.
- Weber P, Bendich A, Schaleh W (1996). Vitamin C and human health – a review of recent data relevant to human requirements. *Int. J. Vit. Nutr. Res.*, 66: 19-30.
- Yates AA, Schlicker SA, Sutor CW (2003). Dietary Reference Intakes: The New Basis for Recommendations for Calcium and Related Nutrients, B Vitamins, and Choline, *J. Am. Diet. Assoc.*, 98: 699-706.