FACTORS CONTRIBUTING TO IODIDE DEFICIENCY IN THE COASTAL REGION OF KENYA

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FACTORS CONTRIBUTING TO IODIDE DEFICIENCY IN THE COASTAL REGION OF KENYA

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A thesis submitted as partial fulfilment for the degree of Master of Public Health; in the Jomo Kenyatta University of

Agriculture and Technology

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DECLARATION

This thesis is my original work and has not been presented to any other examining body for the award of a degree neither has it been submitted to any publication.

Signature ………………………….. Date ……………

Boniface Kahindi Kazungu

This thesis has been submitted with our approval as University supervisors.

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DEDICATION

This proposal is dedicated to my beloved wife Dorothy Kaingu and my son Ndzai David Katana.

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LIST OF ABBREVIATIONS /ACRONYMS

DALY	Disability-Adjusted Life Years
DDT	Dichlorodiphenyltrichloroethane
EA	Enumeration Areas
ICCIDD	International Council for Control of Iodide Deficiency Disorders
ID	Iodide Deficiency
IDD	Iodide Deficiency Disorders.
IIH	Iodide-induced hyperthyroidism
KEMRI	Kenya Medical Research Institute
KNBS	Kenya National Bureau of Statistics
PPM	Parts per million
RDA	Recommended Daily Allowance
SAC	School-age Children (5–14 years)
TGP	Total Goitre Prevalence.
TGR	Total Goitre Rate
UI	Urinary Iodide
UIC	Urinary Iodide Concentration
UIER	Urinary Iodide Excretion Rates
UNICEF	The United Nations Children’s Fund
USI	Universal Salt Iodization
WHO	World Health Organization

ABSTRACT

Iodide is important for synthesis of hormones that regulate growth and development in the body. The Coastal region of Kenya has continued to experience high prevalence of iodide deficiency despite availability of iodized salt and being on the coastline. Iodide deficiency contributes to various health effects both subtle and overt. Iodide deficiency in communities may arise due to several factors including absence of iodide in natural diet, lack of fortification of some dietary salt sources and loss of iodide in fortified salt before consumption. Despite the availability of iodized salt in the Coastal region the prevalence o iodide deficiency has remained high. The factors contributing to the high prevalence of iodide deficiency in the region are unknown. The main objective of this study was to determine the factors contributing to iodide deficiency in Coast region of Kenya. The study employed across-sectional study design. The data was collected in a community survey using a structured interviewer administered questionnaire. The respondents were randomly sampled from the community in selected clusters in the six counties in Coast region of Kenya. The data was analyzed using both descriptive and analytical methods. A total of 292 respondents selected from six counties of the Coast region of Kenya were interviewed. The age of the respondents ranged between 16 – 72 years with the majority 53.7% aged between 20 -39 years. About two-thirds (65%), of the respondents were married, 20% single, 8% widowed and 7% divorced. The majority (64.8%), of the respondents were Christians while 24.2%, 9% and 2% were Muslims, traditionalists and Hindu respectively. Only 38.7% of the respondents were employed (20.7% in formal employment and 18% were self-employed) while the rest (61.3%) were unemployed. Less than half (45.3%), of the respondents had attained primary level of education while 12.7% had tertiary level of education. 292 respondents had no knowledge on food sources of iodide. 292 households interviewed had iodized salt. One fifth (20%), of the households stored salt in open containers, 24% in its package while 56% stored salt in closed containers. Most respondents (82%) stored salt in the kitchen or pantry while 18% stored it in the open. The majority (62.4%) of respondents added salt in the mid of cooking, 16% added salt to raw food before cooking, 11% added salt towards the end of the cooking process, while only 10.6% added salt at the dining table.

All the households interviewed consume iodized salt. The highest proportion (40.8%), of the households had insufficiently iodinated salt, 33% of households had non-iodinated salt, and only 18.4% had adequately iodinated salt while only 7.8% had over iodinated salt. The risk factors associated with iodide deficiency in coast region include; storage of salt in the open, prolonged cooking, low education level and poor knowledge on iodide. Iodide deficiency in the Coastal region results from consumption of low iodide in diet mainly due to practices that lead to iodide loss from salt. Health education on iodide to improve on storage and cooking practices will help prevent iodide deficiency.

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CHAPTER ONE

INTRODUCTION

1.1 Background

Iodide is necessary for the synthesis of thyroid hormones that regulate growth, development and metabolism in the human body. Inadequate intake can result in impaired intellectual development and physical growth (Andersson, De Benoist, Bruno, Darnton-Hill, Ian, Delange, François, 2007; Delange, 2002; Gunnarsdottir, 2012). The range of impairments resulting from iodide deficiency are referred to as iodide deficiency disorders (IDD) and can include foetal loss, stillbirth, congenital anomalies and hearing impairment (Richard, 2006). The vast majority of deficient individuals experience mild mental retardation. This decrease in mental ability and work capacity may have significant socio-economic consequences. Studies implicating iodide deficiency as an underlying cause of mortality are limited. Because of this, few child deaths can be directly attributed to iodide deficiency, but the directly attributable disability-adjusted life year (DALY) losses remain considerable (Andersson, De Benoist, Darnton-Hill, & Delange, 2007).

Iodide deficiency is thought to be a public health problem in a community if goitre is detected in more than 5% of the school-age population (Andersson, Takkouche, Egli, & De Benoist, 2004; Zimmermann, 2004). Prevalence of greater than 30% means that the deficiency is severe. According to iodide status data collected between 1993 to 2003 in 126 countries, the World Health Organization (WHO) estimates that in 54 countries the population has insufficient iodide intake as indicated by a median urinary iodide (UI) below 100µg/l. These countries are classified as iodide deficient: one country is severely deficient, 13 are moderately deficient and 40 mildly deficient. In 43 countries, the population have adequate iodide intake with a median UI between 100 and 199µg/l. Iodide status of these countries is considered as optimal. In Kenya, the prevalence of iodide deficiency was estimated to be about 36.8% and 50.7% in Coast region in sentinel surveys done by assessment of urinary iodide levels in 2006 (Andersson et al., 2007). Iodized salt programs are decreasing the prevalence of iodide deficiency in many regions in the world. However; this reduction is offset by apparent increases in other regions, where public health officials are now aware of the problem because of increased surveillance (Andersson et al., 2007; Zimmermann, 2009).

Iodide deficiency, with endemic goitre as its main clinical manifestation and brain damage and irreversible mental retardation as major public health consequences, is part of the history of the world and Kenya in particular. All regions of Kenya have experienced this health and socioeconomic scourge to some degree. Endemic cretinism, the most severe consequence of iodide deficiency, has not been specifically studied and reported in Kenya as only limited attention has been paid to the public health consequences of iodide deficiency in Kenya until recently (Andersson et al., 2003).

In 1960, the World Health Organization (WHO) published the first global review on the extent of endemic goitre (De Benoist, 2004). This review, covering 115 countries, was instrumental in focusing attention on the scale of the public health problem of iodide deficiency disorders (IDD). It was only in the mid 1980s that the international community committed themselves to the elimination of IDD through a number of declarations and resolutions (Andersson et al., 2007; Zimmermann, 2009). WHO subsequently established a global database on iodide deficiency which now holds surveys dating back from the 1940s to date. Its objective is to assess the global magnitude of iodide deficiency, to evaluate the strategies for its control and to monitor each country's progress towards achieving the international community's goal of IDD elimination. In 1993, the first version of the WHO global database on iodide deficiency was published with global estimates on the prevalence of iodide deficiency, based on total goitre prevalence (TGP), using data from 121 countries (De Benoist, 2004). Since then, the international community and the authorities in most countries where iodide deficiency disorders was identified as a public health problem have taken measures to control iodide deficiency, in particular through salt iodization programmes – the WHO recommended strategy to prevent and control iodide deficiency. As a result, it is assumed that the iodide status of populations throughout the world has improved over the past two decades (Bruno de Benoist, 2004).

Iodide deficiency has been recognized in Kenya for many years now. At the beginning of the 19th century, it was suggested that the use of salt fortified with iodide would lead to good health in people living in iodide deficient areas (KNBS, 2010). After the pioneering work of Swiss doctors that demonstrated that iodide deficiency was indeed the cause of goitre, attempts began to locally iodize salt using a hand-and-shovel method (Diosady, Yusufali, Oshinowo, & Laleye, 2006; Kibatu, Nibret, & Gedefaw, 2014). In Kenya iodized salt was introduced in the 1980s on a large scale in order to eliminate iodide deficiency. Due to various factors the availability of iodized salt progressed slowly. Today, over 90% of households consume iodized salt and about 70% of the salt used in industrial food production is iodized(KNBS, 2010).

1.2 Problem statement

The Coast region has continued to experience high prevalence of iodide deficiency in school age children (SAC)(De Benoist, 2004). Though there is no data for ID among women of reproductive age (WRA); it can be assumed to compare closely to that in SAC. Moderate iodide deficiency in WRA leads to goitre, severe deficiency leads to hypothyroidism, irreversible mental retardation and cretinism in their offspring characterized by mental and growth retardation if iodide deficiency occurs during the most critical period of brain development from the foetal stage up to the third month after birth (Richard 2006). In severely iodide deficient endemic areas, cretinism may affect up to 5–15% of the population (Richard 2006). While cretinism is the most extreme manifestation of iodide deficiency, of considerably greater significance are the more subtle degrees of mental impairment of children leading to poor school performance, reduced intellectual ability and impaired work capacity. Iodide deficiency in children leads to hypothyroidism with its metabolic and developmental consequences. Iodide deficiency remains one of the commonest causes of preventable mental retardation and low intelligent quotient (IQ) (Bleichrodt & Born, 1994). Low levels of iodized salt consumption may be due to various factors including ignorance, poverty, unavailability, food insecurity, post production losses and the effects of goitrogenic factors. Medical management of the effects of iodide deficiency is expensive and a burden in developing countries hence the emphasis on prevention. There are also clusters of populations in the coastal region that have access to and probably consume raw salt. These include communities living around Gongoni salt farms in Magarini subcounty and Mbogolo area in Kilifi south subcounty. The sentinel surveys in 2006 revealed a high prevalence of iodide deficiency in school age children i.e. 50.7% in the Coast region (Andersson, De Benoist, Bruno, Darnton-Hill, Ian, Delange and François , 2007; De Benoist, 2004). There is lack of information on the factors contributing to the high prevalence of iodide deficiency in Coast region of Kenya. This limits the ability to carry out data-driven program management decisions.

1.3. Justification of the study

Despite the availability and consumption of iodized salt being reported to be above 90% the prevalence of iodide deficiency in the Coast region of Kenya was 50.7% (KNBS, 2010). This study contributes to understanding of the risk factors contributing to iodide deficiency in Coast region of Kenya; which can be used as a basis for planning, monitoring and evaluating fortification and iodide supplementation programs in the region. The results of the study will be disseminated among the community to gain insight and knowledge on factors that may lead to iodide deficiency in the community. This knowledge may influence behavioural changes towards improved iodide intake and prevention of iodide deficiency disorders. The information provided by the study will be used to prevent iodide efficiency in the population hence improve growth and development in children. It is part of Ministry of Health (MoH) mandate to track the progress made towards the elimination of iodide deficiency. It’s hoped that the data will help the Ministry of Health appreciate the progress made in improving iodide nutrition over the past decade and also to be aware deviations.

1.4 Objectives

1.4.1 General objective

The general objective of the study is to determine factors contributing to iodide deficiency in the Coastal region of Kenya.

1.4.2 Specific objectives

1.4.2.1 To determine the socio-demographic characteristics of women heads of households in the Coastal region.

1.4.2.2 To determine the proportion of households consuming iodized salt in the Coastal region.

1.4.2.3 To determine the levels of iodide in salt in households in Coastal region.

1.4.2.4 To determine factors contributing to consumption of low iodide in Coastal region.

1.4.3 Research questions

1.4.3.1 What are the socio-demographic characteristics of women heads of household in the Coastal region?

1.4.3.2 What is the proportion of households consuming iodized salt in the coastal region?

1.4.3.3 What are the levels of iodide in salt in households in Coastal region?

1.4.3.4 What are the factors contributing to consumption of low iodide in Coastal region?

CHAPTER TWO

LITREATURE REVIEW

2.1 Functions of iodide in the body

The thyroid gland is of endodermal origin, arising from two main structures, the primitive pharynx ad the neural crest. It arises as a median downgrowth in the floor of the pharynx during third week of gestation. The parafollicular cells are derived from the neural crest cells. It begins functioning at about the 10^{th} week of foetal life (Richard, 2006; Stein & Eisenberg, 1998).

The thyroid gland is located in the anterior side of the neck; it consists of two lobes connected by an isthmus; normally weighs 12 – 20 grams and is soft in consistency. The thyroid gland produces two related hormones, thyroxine (T_4) and triiodothyronine (T_3). These hormones play a critical role in cell differentiation during development and help maintain thermogenic and metabolic homeostasis in the human body. Disorders of the thyroid can lead to hyperthyroidism or hypothyroidism (Hay, Levin, Sondheimer, & Deterding, 2004; Kasper, 2005). Thyroid hormones regulate metabolic processes in most cells, as well as playing a determining role in the process of early growth and development of most organs, especially that of the brain. In humans, most of the growth and development of the brain occurs during the foetal period and the first two to three years of postnatal life (Andersson et al., 2007).

Iodide is an element that is needed for the production of thyroid hormone. The body does not synthesize iodide, so it is an essential trace mineral element required as part of diet. Iodide is found in various foods. Iodide is an essential micronutrient present in the human body in minute amounts (15–20µg per day), almost exclusively utilized in the thyroid gland. It is an essential component of the thyroid hormones; thyroxine (T_4) and triiodothyronine (T_3); with iodide comprising 65% and 59% of their weights, respectively (Andersson et al., 2007). If you do not have enough iodide in your body, you cannot make enough thyroid hormone.

After iodide enters the thyroid, it is oxidized in an organification reaction and added to tyrosine in thyroglobulin molecules. The iodotyrosine molecules are coupled to produce thyroxine and triiodothyronine (Kasper, 2005). Iodide uptake is a critical first step in thyroid hormone synthesis. Some ingested iodide is bound to albumin while free iodide is excreted in urine. Thyroid gland extracts about 10 – 25% of iodide in circulation; this can rise to over 70% depending on demand. Thyroid gland function is regulated by thyrotropin/thyroid stimulating hormone (TSH) from pituitary gland and thyrotropin releasing hormone (TRH) from the hypothalamus through a feedback mechanism. The levels of iodide in urine and thyroglobulin are important indicators of thyroid function (Kasper, 2005).

Iodide is important in medicine, in both radioactive and non-radioactive forms. Apart from the synthesis of hormones iodide compounds have other uses in the body including;

- Overall healthy thyroid function**.**
- In nuclear medicine for radiological diagnostics, Diatrizoic acid (iodide in water) is a radiocontrast material for intravenous injection used in computer tomography, angiography and radiotherapy procedures in brachytherapy,
- As a topical disinfectant for external wounds with antifungal and antimicrobial effects and as a water purifier in water treatment process, in different forms e.g. Tincture of iodide: iodide in ethanol or iodide and sodium iodide in a mixture of ethanol and water; Lugol's iodide: iodide and iodide in water alone, forming mostly triiodide and Povidone iodide an iodophor.
- Major uses of ^{131}I include the treatment of thyrotoxicosis (hyperthyroidism) and some types of thyroid cancer that absorb iodide.
- The ^{131}I is thus used as direct radioisotope therapy to treat hyperthyroidism due to Graves' disease, and sometimes hyperactive thyroid nodules.

- The ^{131}I isotope is also used as a radioactive label for certain radiopharmaceuticals that can be used for therapy, e.g. ^{131}I-metaiodobenzylguanidine (^{131}I-MIBG) for imaging and treating pheochromocytoma and neuroblastoma.
- In all of these therapeutic uses, ^{131}I destroys tissue by short-range beta radiation.
- Non-radioactive potassium iodide tablets are used to prevent effects of nuclear emissions.
- In health care iodide is used in surgical preparation for goitre, treatment of acute thyrotoxicosis, prevention of arthritis, is an expectorant and is a detoxifier.
- In industry, silver iodide is used in photography as major ingredient of traditional photographic film,
- Silver iodide is also used for cloud seeding; as a catalyst in chemical reactions for production of acetic acid, and printing inks and dyes.
- Iodide is also an important nutrient component of animal feeds used widely in animal husbandry as ethylenediammonium diiodide (EDDI).
- An Organoiodide compound erythrosine is an important food coloring agent.
- Perfluoroalkyl iodides are precursors to important surfactants, such as perfluorooctanesulfonic acid.

2.2 Food sources of iodide

Iodide is present naturally in soil and seawater from where it gets into the food chain. The availability of iodide in foods differs in various regions of the world. Individuals can maintain adequate iodide in their diet by using iodized table salt, by eating foods high in iodide, particularly dairy products, seafood, meat, some breads and eggs, and by taking multivitamins fortified with iodide. Sea water is rich in iodide, and the iodide content of sea foods like fish and shellfish is also high. Endemic goitre is rare therefore in populations living along the sea (Delange, 2002; Hay et al., 2004; Richard, 2006). According to the multicenter study of 2002 and Creswell & Michael 2009, the commonest sources of dietary iodide include; breads, cheese, dairy milk, eggs, yoghurt, ice cream, iodide containing multivitamins, iodized table salt, saltwater fish, seaweed, shellfish, soya milk and soya sauce.

1.3 Causes of iodide deficiency.

Iodide ions in seawater are oxidized to elemental iodine, which is very volatile and sublimes into the atmosphere and is returned to the soil by rain to get into the food chain, completing the cycle. Iodide cycling may be slow and incomplete and soils and ground water become deficient in iodide. Crops grown in these soils will be low in iodide, and humans and animals consuming food grown in these soils become iodide deficient. Iodide deficient soils are most common in inland regions, mountainous areas and areas of frequent flooding(Zimmermann, 2010). This may be compounded by the leaching effects of snow, water and heavy rainfall, which removes iodide from the soil. Iodide deficiency in populations residing in iodide deficient areas will persist until or unless iodide enters the food chain through supplementation (Gitau, 1988; Zimmermann, 2010; Zimmermann, 2009).

Since the body does not synthesize iodide, it relies on the diet to get enough iodide. Thus, iodide deficiency is caused by not having enough iodide in the diet (De Benoist, 2004). Iodide is deficient in the water and native foods in the Pacific west and the Great Lakes areas of the United States. Deficiency of dietary iodide is even greater in certain Alpine valleys, the Himalayas, the Andes, the Congo and the highlands of Papua New Guinea (De Benoist, 2004; Gidey et al., 2015; Richard, 2006).

2.4 Prevalence of iodide deficiency in the world

Iodide deficiency (ID) can lead to goitre and mental retardation in infants and children whose mothers were iodide deficient during pregnancy. Endemic goitre is the commonest manifestation of ID (Andersson et al., 2003; Gitau, 1988, WHO 2004). The Prevalence of ID, as measured by urinary iodide (UI) in general population and in school age children (SAC) in 2007 in Africa was (41.5%, 40.8%) Americas (11.0%, 10.6%) Eastern Mediterranean (47.2%, 48.8%) Europe (52.0%, 52.4%) Southeast Asia (30.0%, 30.3%) Western Pacific (21.2%, 22.7%) with a worldwide total of 30.6% and 31.5%. The households with access to iodized salt in Africa were (66.6%) Americas (86.8%) Eastern Mediterranean (47.3%) Europe (49.2%) Southeast Asia (61.0%) Western Pacific (89.5%) with a worldwide aveage of 70% (Zimmermann, 2009).

In an iodide status assessment done by WHO between 1993 and 2003, the changes in total goitre prevalence (TGP) in Africa was 15.6% to 28.3%; America was 8.7% to 4.7%; Southeast Asia was 13.0% to 15.4%; Europe was 11.4% to 20.6%; East Mediterranean was 22.9% to 37.3% and 9.0% to 6.1% in West pacific. WHO 2004 further estimated that about 36.5% of SAC and 35.2% of the total population had inadequate iodide intake as measured by UI; this translated to about 285.4 million SAC and 988.7 million people suffering iodide deficiency.

According to Richard and Hal, 2006 in Nelson's textbook of pediatrics*,* about 800 million people live in iodide deficient areas of the world including mountainous regions of central Europe, Asia, and South America, as well as lowland regions of Greece, the Netherlands, and Finland. In these population groups, endemic goitre occurs in at least 10% of the population and there may be as many as 200 million endemic goitres worldwide. Endemic goitre exists in a population when >5% of 6-12 year-old children have enlarged thyroid glands (Zimmermann, 2009). Sporadic goitre occurs in less than 10% of any population group. Its prevalence is about 4% in the United States. It is more common in women than men (8:1), and onset is frequently noted at the time of puberty, pregnancy and menopause(Dugassa, 2013; Fuse et al., 2011).

As noted in the 2007 WHO publication; before the 1920s, iodide deficiency was common in the Great Lakes, Appalachian, and Northwestern U.S. regions and in most of Canada. Approximately 40% of the world's population remains at risk for iodide deficiency. Iodide deficiency is estimated to be between 3 and 4% in WRA in the United States (Kasper, 2005). Iodide deficiency has been eradicated in North America by effective prophylactic measures but continues to be a major health problem in many developing countries. Goitre occurs when iodide intake or excretion in urine is less than 20mg/d (Stein & Eisenberg, 1998).

According to the International Council for the Control of Iodide Deficiency Disorders (ICCIDD) estimate in 2011, about 12 million school age children in Ethiopia live with inadequate iodide; about 66 million people are prone to the risk of iodide deficiency disorders; and Ethiopia is the 1st of the top iodide deficient countries in the world based on national median urinary iodide concentration < 100 µg/L(Gitau, 1988; Girma Kibatu, Endalkachew Nibret, & Molla Gedefaw, 2014).

The most recent data on iodide nutrition status of school aged children and women (2005-2010) indicated that only between 15 and 20% of the households used adequately iodized salt; the prevalence of goitre in school aged children was greater than 30% in goitre endemic regions and the median national urinary iodide excretion concentration in school age children was 24.5µg/L In a cross-sectional community based study conducted in women of childbearing age of 15 to 49 years, the total goitre prevalence (weighed) was 35.8 %; 24.3% were palpable and 11.5% was visible goitres. The report showed that more than 6 million women were affected by goitre in 2007(Kibatu et al., 2014).

Prevalence of iodide deficiency in Kenya.

According to Multicenter study in a 1994 National Micronutrient Survey conducted in 45 districts in Kenya, the total goitre rate was 16%. Three had no goitre problems, while 30 had mild ID with goitre prevalence between 5 and 19%, 7 had moderate problem (Total goitre rate -TGR 20-29%) and 5 districts were noted to have goitre prevalence greater than 30%. Limited survey data from Mombasa, Nairobi and Rift Valley collected in 1984 indicated TGR prevalence around 20%. The national prevalence was 16.3%. A multicenter study done in 1995 in Kenya found a TGR of 14% in Kericho, 11% in Kiambu, and 9.5% (Nairobi). A Mean urinary iodide of 62µg/L was observed in a sub-sample of the survey population in the National Micronutrients Survey in 1994 as reported by De Benoist in 2004 (Gitau, 1988, De Benoist 2004). The multicenter study of 1995 also reported a mean urinary iodide concentration of 125, 378, and 580µg/L in kericho, kiambu and Nairobi respectively (Delange, 2002; Kulwa, Kamuzora, & Leo, 2006). According to sentinel data based on UI the prevalence of ID in Kenya was 36.8% (Davies, 1994; De Benoist, 2004).

Data on the prevalence of iodide deficiency among children aged 8-10 years old indicated a reduction in goitre rates from 16% in 1994 to 6% in 2006, attributed to the consumption of iodized salt by over 90% of Kenyan households (Delange, 2002). However, based on urinary iodide excretion rates (UIER) 25% of the studied children still have inadequate intake (Davies, 1994; De Benoist, 2004).

Table 2.1 Iodide status in sentinel districts in Coast Region

	2004; 8 – 11years; both sexes		2006; 9 – 14years; both sexes	
District #	UI <100ug/l prevalence %	TGP %	UI <100ug/l prevalence %	TGP %
Kilifi	5.4	7.9	ND	ND
Kwale	2.6	10.5	44.0	18
Lamu	42.9	57.8	40.6	36.7
Mombasa	ND	10.7	68.2	15.2
Taita Taveta	46.2	4.5	24.0	0.0
Malindi	ND	ND	64.9	24.0
Coast prov.	ND	ND	50.7	26.2
Kenya	36.7	15.5	36.8	6.2

- now counties; ND – no data available

Source: (De Benoist, 2004).

2.5 Health effects of iodide deficiency.

Deficiencies of essential micronutrients in human nutrition have a significant impact on health and development of children in many countries. Particularly, iodide deficiency is a serious public health problem in Kenya (Kibatu et al., 2014; Muture & Wainaina, 1994). Iodide deficiency in the diet can result in a variety of health problems such as goitre, mental and physical retardation (cretinism), spontaneous abortions, stillbirths, congenital abnormalities, and infant and young child death. Iodide deficiency impedes children's learning ability. The clinical and sub-clinical manifestations of iodide deficiency are collectively termed as Iodide Deficiency Disorders (IDD) (Kibatu et al., 2014). Maternal iodide deficiency causes endemic cretinism in about 5-15% of neonates who develop endemic goitres (Stein & Eisenberg, 1998). The effects of ID differ depending on the age of the affected person; as follows,

Health effects of iodide deficiency in a foetus (unborn child).

The consequences of ID during pregnancy result from the impaired synthesis of thyroid hormones in both the mother and the foetus. In addition, maternal hypothyroxinaemia results in a lowering in the maternal transplacental transfer of thyroxine during the early phase of foetal development – the first and second trimesters – during which the supply of thyroid hormones to the foetal brain comes almost exclusively from the mother. The long-term consequence of foetal hypothyroxinaemia occurring during early gestation is the development of a neurological syndrome, which includes severe mental retardation, spastic diplegia, hearing defects and squint. These symptoms correspond to what used to be called neurologic endemic cretinism. On the other hand, when foetal and neonatal hypothyroxinaemia occur later, after the first phase of maximal brain growth velocity, the long-term clinical consequence is severe thyroid insufficiency with stunted growth, myxoedema, delay in sexual development, but with a lesser degree of neurologic impairment and mental deficiency. This corresponds to the previous syndrome of myxoedematous endemic cretinism. Some of the extreme consequences of congenital hypothyroidism include; abortions, stillbirths, congenital anomalies, increased perinatal mortality, endemic cretinism and deaf mutism (Andersson et al., 2007; Zimmermann, 2009). Pregnant women with the third trimester urinary iodide concentrations (UIC) between 100 - 149µg/l had lower risk of having a small for gestational age newborn than women with urinary iodide concentrations (UIC) below 50µg/l (Alvarez-Pedrerol et al., 2009).

Health effects of iodide deficiency in Neonates (below one month old)

Iodide deficiency results in increased perinatal mortality, low birth weight on average and a higher rate of congenital anomalies. Even mild and moderate iodide deficiency, if occurring during the neonatal period, affects the intellectual development of the child (Bogale et al., 2009). This indicator appears to be a particularly sensitive tool in the evaluation of the iodide status of a population and in the monitoring of iodide intervention programmes. Other consequences include neonatal goitre, neonatal hypothyroidism, endemic mental retardation and increased susceptibility of the thyroid gland to nuclear radiation (Andersson et al., 2007; Hay et al., 2004; Zimmermann, 2009).

Health effects of iodide deficiency children and adolescents (from one month to 12 years, from 12 years o 18 years).

In addition to its impact on brain and neuro-intellectual development, ID at any period of life, including during adulthood, can induce the development of goitre with mechanical complications and/or thyroid insufficiency. Other consequences of iodide deficiency include hypothyroidism, impaired mental function, retarded physical development and increased susceptibility of the thyroid gland to nuclear radiation. The symptoms of hypothyroidism include: central nervous system; forgetfulness, dementia and cerebellar ataxia; cardiovascular system; bradycardia, pericardial effusion and hypertension; respiratory system; depressed ventilatory drive, pleural effusion and sleep apnea; gastrointestinal system; constipation and hypomotility; muscular system; delayed tendon reflexes, muscle stiffness, cramps, increased muscle volume and weakness; skin; dry, rough, hyperkeratosis and non-pitting puffiness; metabolism; basal metabolic rate decreased, cold intolerance and weight gain (Andersson et al., 2007; Hay et al., 2004; Zimmermann, 2009).

Health effects of iodide deficiency in adults.

Goitre, with its complications, hypothyroidism, impaired mental function, spontaneous hyperthyroidism in the elderly, iodide induced hyperthyroidism (IIH) and increased susceptibility of the thyroid gland to nuclear radiation (De Benoist, 2004; Zimmermann, 2009). A meta-analysis of 19 studies conducted in severely iodide deficient areas in the world showed that iodide deficiency is responsible for a mean intelligent quotient (IQ) loss of 13.5 points in the population (Bleichrodt & Born, 1994). A high degree of apathy has been noted in populations living in severely iodide deficient areas. This affects the capacity for initiative and decision-making, indicating that iodide deficiency constitutes a hindrance to the social development of communities. It is also a major teratogen at the community level (Andersson et al., 2007; Zimmermann, 2009).

Although the most visible manifestations of iodide deficiency are goitre and cretinism, many people are affected with less severe deficiencies that are not obvious clinically and not easy to measure but affect wellbeing and productivity. In Ethiopia, iodide deficiency disorders have been recognized as a major public health problem for the last six decades and remain a major national threat to the health and development of its population (Kibatu et al., 2014).

2.6 Benefits of the prevention of iodide deficiency.

Health benefits of prevention of iodide deficiency.

The health benefits that are realized with the elimination of iodide deficiency are immense, and lie in the benefits that come with the elimination of all the health effects mentioned above under the various age cohorts.

Social benefits of the prevention of iodide deficiency.

The social benefits of the elimination of iodide deficiency (ID) have been extensively evaluated on the basis of reviews of data collected from several regions of the world. Its most important effects are on the growth and development of the foetus, the neonate and the child. Potential benefits in preventing ID are then much increased, including more and better education for children, greater productivity throughout life, and a better quality of life. The positive effects of mitigating ID in individuals and communities include a reduction in mental deficiency, deaf-mutism and hypo- and hyperthyroidism, as well as more subtle retention of mental potential, not easily measured on intelligent quotient (IQ) tests (Andersson et al., 2007).

Economic benefits of the prevention of iodide deficiency.

The benefits of ID control include improved neurological, mental, auditory and speech capabilities as well as skeletal growth. The resulting higher work productivity, reduced costs and losses due to reduced absenteeism and higher achievements by students help improve school performance. Using various assumptions, the benefit of salt iodization in terms of productivity and of the money that would be saved on the management and support of those affected, resulted in a Cost: Benefit ratio of 1: 3. Since the increased intelligent quotient of the children would produce economic benefit only after several years, it was assumed that such an increase would begin to take place 15 years later but that after an initial delay, the benefit of the programme would be continued for as long as an iodide deficiency prevention and control programme was in place; and the benefit of reducing iodide deficiency among children, in terms of improvement in their lifetime earnings, also considerably exceeded the cost of the interventions (Andersson et al., 2007).

2.7 Goitrogenic factors

Goitrogens are substances including foods that have the capability to alter how the human body absorbs and processes iodide; they suppress thyroid function and can induce hypothyroidism and goitre. Although the relation of iodide deficiency (ID) to endemic goitre is well established, other factors may be involved. A variety of naturally occurring agents have been identified that might be goitrogenic in man. These are active only if iodide supply is limited and/or goitrogen intake is of long duration (Davies 1994, Zimmermann, 2009). In the same publication Zimmermann lists these goitrogenic substances to include: Sulfurated organic compounds like thiocyanate, isothiocyanate, goitrin and disulphides, flavonoids like polyphenols, polyhydroxyphenols and phenol derivatives; pyridines, phthalate esters and metabolites; polychlorinated (PCB) and polybrominated (PBB) biphenyls; organochlorines like dichlorodiphenyltrichloroethane (DDT), polycyclic aromatic hydrocarbons (PAH), inorganic iodide and lithium.

According to Stoewsand 1995, certain raw foods have been identified as lightly goitrogenic. However proper cooking inactivates some goitrogens. These foods include: cassava, soybeans, pine nuts, peanuts, millet, strawberries, pears, peaches, spinach, sweet potatoes and vegetables of brassica family like broccoli, cauliflower, brussel sprouts, cabbage, mustard, kale, turnips and rape seed (canola oil). Glucosinolates, sulfur-containing phytochemicals found in vegetables of brassica family have been associated with goitre and a general inhibition of iodide uptake by the thyroid (Stoewsand, 1995).

Babassu (*Orbignya phalerata*), a palm-tree coconut fruit, mixed with mandioca (*Manihot utilissima*) is the staple food of people living in the endemic goitre area of Maranhao in Brazil, where goitre prevalence among schoolchildren was still 38% in 1986 despite an adequate iodide intake in most of the population. In a study on this phenomenon; the edible parts of babassu produced significant in vivo antithyroid effects in rats on a high iodide intake, as well as distinct and reproducible antithyroid and anti-thyroid peroxidase activities in in-vitro systems, their action being similar to that of the thionamide-like antithyroid drugs propylthiouracil and methimazole (Gaitan et al., 1994. Davies 1994).

2.8 Prevention of iodide deficiency.

As with many diseases, it is better to prevent the problem rather than to treat it. Over the last 80years, world-wide efforts have been made to eliminate iodide deficiency (ID). Traditionally, populations living close to the sea have been less at risk because marine foods, including seaweed, tend to be high in iodide. Other ways of replacing iodide have been through supplementation, tinctures of iodide, iodized oil, both intramuscular injections and oral, and by adding it to foods, especially iodized salt but also iodized water supplies and other food vehicles. Overwhelmingly, salt iodization is the intervention of choice, with the others ancillary to access hard-to-reach populations at high risk. Indirect iodization has also been shown to be effective in correcting ID. Adding potassium iodate into irrigation water has been reported as highly successful in Xinjiang, China: for example, the infant mortality rate dropped by 50% (Tonglet , Bourdoux , Minga , & Ermans 1992; van der Reijden, Zimmermann, & Galetti). Finland, besides fortifying their table salt, has been fortifying animal fodder and animal salt licks hence the iodide content of foods derived from animal sources have increased. In a review by Davies 1994, he demonstrated that a multidisciplinary approach to prevention of iodide deficiency would yield better results (Andersson et al., 2007; Davies, 1994).

Iodide prophylaxis achieved by the fortification of table salt and foods such as bread fortified with iodide (iodized salt in bread) and cereal eliminated the problem of iodide-deficient goitre (Andersson et al., 2007; Richard, 2006). In areas such as the United States, where iodide is provided in foods from other areas and in iodized salt, endemic goitre has disappeared. Iodized salt in the United States contains potassium iodide (100µg/g) and provides excellent prophylaxis. Further iodide intake in the United States is contributed by iodates used in baking (potassium iodide of baker's salt), iodide-containing colouring agents, and iodide-containing disinfectants used in the dairy industry; Milk has had its iodide content raised in many dairy-producing countries consequent to the use of iodophors in the dairy industry (e.g. to clean the teats). Iodide-rich milk thus became a major source of iodide in many countries in northern Europe, as well as in Australia, the United Kingdom and the USA (Andersson et al., 2007; Gidey et al., 2015; Hay et al., 2004).

United States Recommendations - The Institute of medicine in the USA has set the recommended daily allowance (RDA) for iodide in adult men and women at 150µg per day. Individuals who add table salt to their food regularly should use iodized salt. One teaspoon of iodized salt contains approximately 400µg iodide. Most iodide-containing multivitamins have at least 150µg iodide, but only about half of the types of multivitamins in the United States contain iodide. The optimum intake of iodide for adults is about 100 – 150µg daily (Delange, 2002; Zimmermann et al., 2004)(Richard and Hall, 2006). The RDA is 220µg iodide per day for pregnant women and 290µg iodide per day for breastfeeding women. Because the effects of iodide deficiency are most severe in pregnant women and their babies, the American thyroid aassociation has recommended that all pregnant and breastfeeding women in the U.S and Canada take a prenatal multivitamin containing 150µg iodide per day (Andersson et al., 2007).

Prevention of iodide deficiency by the introduction of iodized salt has virtually eliminated the “goitre belt” which includes Northern continental region of the United States of America encompassing the region extending from the Rockies through the Great lakes basin to Western New York. However, many other parts of the world do not have enough iodide available through their diet and iodide deficiency continues to be an important public health problem globally (Andersson et al., 2007).

Table 2.2 Recommendations for iodide intake (µg/day) by age or population group

Age or population group	U.S. Institute of Medicine	Age or population group	World Health Organization
Infants 0–12 months	110-130	Children 0-5 years	90
Children 1-8 years	90	Children 6-12 years	120
Children 9-13 years	120		
Adults ≥14 years	150	Adults >12 years	150
Pregnancy	220	Pregnancy	250
Lactation	290	Lactation	250

(Zimmermann, 2004).

According to iodide deficiency disorders (IDD), by Zimmermann publication of 2004, ID can be prevented by consumption of iodide fortification in iodized salt, iodized oil, iodized bread and iodized water. Iodide supplementation can be through daily consumption of fortified foods or as a single annual dose of 400mgs in iodized oil in adults or 200mgs in children. In countries or regions where <90% of households are using iodized salt and the median urinary iodide concentration in school age children is <100µg/L, WHO recommends iodide supplementation in pregnancy and infancy (Zimmermann, 2004, 2009).

A school-based program providing food fortified with multiple micronutrients could be a cost-effective and sustainable strategy to improve health and cognitive function of school children (Berhanu, Wolde Michael, & Bezabih, 2004; Gitau, 1988). Multi-micronutrient fortified biscuits including iron (6mg), zinc (5.6mg), iodide (35µg), and vitamin A (300µg retinol equivalents) were given 5 days per week for 4 months. Multi-micronutrient fortification significantly improved the concentrations of haemoglobin (1.87g/L; body iron (0.56mg/kg body weight; plasma zinc (0.61µmol/L; plasma retinol (0.041µmol/L; and urinary iodide (22.49µmol/L; Fortification reduced the risk of anaemia and deficiencies of zinc and iodide by >40%. Multi-micronutrient fortification of biscuits is an effective strategy to improve the micronutrient status of schoolchildren (Gidey et al., 2015; Nga et al., 2009).

Universal salt iodization (USI) programme.

The main intervention strategy for iodide deficiency (ID) control and prevention is universal salt iodization including all salt for human consumption, i.e. table salt, salt used in processed foods, and that used for animal feeds is iodized (Andersson et al., 2007; Davies, 1994). Indeed, elimination of ID has been a major goal of the WHO. Iodized salt has been the mainstay of prevention for ID worldwide (Delange, 2002). The universal salt iodization (USI) programme was established in Kenya through legislation enacted in 1978 and revised in 1988 (Muture and Wainaina 1994). The programme included activities aimed at creating awareness through information, education and communication (IEC) strategies. USI is a collaborative programme that includes the nutrition program in Ministry of Health (MOH), in collaboration with Kenya Bureau of Standards (KEBS) and is responsible for salt iodide monitoring. An iodide deficiency disorders (IDD) laboratory was set up with support from UNICEF. In 1987 a National Council for the Control of Iodide Deficiency Disorders (NCCIDD) was established to create a proposal to prevent iodide deficiency disorders (Davies, 1994; Muture & Wainaina, 1994).

Salt iodization has been a remarkably successful intervention as it is feasible, cheap, safe, rapidly effective and widely accepted. USI is currently the best strategy based on the following advantages;

- salt is consumed by everyone and consumption is fairly stable throughout the year;
- salt production is usually in the hands of few producers hence easy to control and monitor;
- salt iodization technology is easy to implement and available at a reasonable cost;
- the addition of iodide to salt does not affect its colour, taste or odour;
- the quality of iodized salt can be monitored at the production, retail and household levels; and
- salt iodization programmes are easy to implement (De Benoist, 2004; Gitau, 1988).

Iodide can be added to salt as potassium iodide (KI), potassium iodate (KIO_3) or sodium iodide.
Potassium salts are the most frequently used. Although slightly more expensive than iodide, the iodate salt is preferred, especially for moist, tropical conditions and where storage conditions are likely to be less than optimal, because it is less soluble and more stable than iodide (Andersson et al., 2007).

Certain preconditions are needed to ensure adequate salt iodization, availability and consumption; for the success of the programme. Local production and/or importation of iodized salt in a quantity that is sufficient to satisfy the potential human demand (approximately 4–5 kg/person per year); ninety percent of salt for human consumption must be iodized according to government standards for iodide content; the percentage of food-grade salt with an iodide content of at least 15ppm, in a representative sample of households, must be equal to or greater than 90%; and iodide estimation at the point of production or importation, and at the wholesale and retail levels, must be determined by titration; at the household level, it may be determined by either titration or certified kits (Andersson et al., 2007).

A major focus in the global strategy to eliminate iodide deficiency disorders since 1990 is to introduce universal salt iodization (USI) in deficient areas. Iodide deficiency disorders and USI program in Ethiopia started in 1989, but slowed down drastically in 2000s due to the Ethio-Eretria war when importing iodized salt from the red sea ceased. In 2005, the government of Ethiopia replanned strategies for the achievement of virtual elimination of iodide deficiency disorders by the year 2015 through universal salt iodization. The government revitalized and launched universal salt iodization initiatives in 2009/10 to maintain universal iodized salt distribution throughout the country. It has also passed salt regulation requiring that salt for human consumption should be iodized since March 2011. Despite some progress in the revitalization of the USI, the country still has one of the highest prevalence of iodide deficiency and one of the weakest salt iodization programs (Kibatu et al., 2014).

Determination of salt iodide level

Assuming an average salt consumption of 10g of salt per capita per day, a loss of iodide of some 20% between production and retail and another 20% during food processing, to achieve the recommended level of iodide of 150μg per person for adults, iodide in the salt should be in the range of 20–40mg/kg (20–40ppm). The packaging of iodized salt is very important. To avoid losses as high as 75% over a period of nine months, waterproof packaging is required (M. Eltom, Karlsson, Kamal, Boström, & Dahlberg, 1985; Zimmermann, 2008). However, due to hypertension prevention strategies that require restriction of salt consumption to less than 5g of salt per capita per day, it means the levels of salt iodization shall have to be reviewed upwards (Zimmermann 2008).

The recommended minimum daily requirement of iodide varies from 150 to 200μg. There is no universal specification for the level of iodide to be added to salt to achieve this recommended iodide intake. Numerous factors influence the selection of an appropriate level for a given population, including: per-capita consumption of salt in the region; the degree of iodide deficiency in the region; transit losses and shelf life required. Per-capita consumption of salt in different countries varies over a wide range, from about 3 to 20g per day.

Table 2.3: Salt iodide level determination.

Assume that the per capita daily requirement of iodide is 200µg;
Assume that the per capita salt consumption is 10g per day.
Level of iodide required in salt is 200µg per 10g (1g = 1 million µg) or 20ppm;
Assume that half of the iodide may be lost in transit and storage;
Level of iodization required = 40ppm = 40 * 1.685 ppm KIO_3 = 67ppm KIO_3

SOURCE; (Milczarek, Stepniak, Lewinski, & Karbownik-Lewinska, 2013; Zimmermann, 2008)

Post production losses.

A study done by Dawit et al, (2010) to assess the post-production losses in iodide concentration of salt in northern Ethiopia; showed the concentration of iodide in salt at the production site was 57.9±15.31mg/kg; the concentration of iodide in salt at the retailers was 41.3±14.3mg/kg and the mean concentration of iodide in salt sampled from the study households was 25.1±22.5mg/kg. The average decrease in iodide concentration of salt samples from the production to the retailer level was 29% and 50% from the retailer to the consumer level. On average, the iodide concentration was reduced by 57% from the production to the consumer level. Taking into account the observed losses in the study and those expected during cooking, a concentration of 119.2mg/kg is needed at the production site to protect the consumers against iodide deficiency through USI programme (Dawit, 2010).

Potassium iodide in salt is not very stable and can easily be lost by oxidation to iodine if the iodized salt is subjected appreciably to any of the following conditions: moisture in the salt, humid or excessively aerated environment; exposure to sunlight; exposure to heat; acid reaction in the salt; or presence of impurities. Impurities that provide moisture at the salt surface have the most deleterious effect. Iodides are fairly soluble in water. High humidity results in rapid loss of iodide from salt iodized with potassium iodide, ranging from 30% to 98% of the original iodide content. In everyday life, iodides are slowly oxidized by atmospheric oxygen in the atmosphere to give free iodine. Evidence for this conversion is the yellow tint of certain aged samples of iodized salts and some organoiodide compounds. The oxidation of iodide to iodine in air is responsible for the slow loss of iodide content in iodized salt if exposed to air. Some salts use iodate to prevent the loss of iodide. It can also be lost if the iodized salt packages become damp, resulting in the migration of iodide from the salt to the fabric, and subsequent evaporation if the fabric is pervious. Solid low-density polyethylene packaging protected the iodide to a great extent. High losses occur from woven high-density polyethylene bags, which are often the packaging material of choice in tropical countries(Adejo & Enemali, 2013). This loss can be lessened when the salt iodized with potassium iodate is very pure (99.5%) and dry (moisture less than 0.1%), and by the addition of stabilizers such as sodium thiosulfate and calcium hydroxide, and/or drying agents such as magnesium carbonate or calcium carbonate. However, in most impure salt, potassium iodate stability is poor due both to oxidation and to migration and segregation in the presence of moisture (Gidey et al., 2015; Milczarek et al., 2013). Studies done in Kenya and Nigeria on the stability of potassium iodate in salt confirmed iodide retention values of up to 90% or more were obtained during the three-month study (Diosady et al., 2006; Oshinowo, Diosady, Yusufali, & Wesley, 2007).

Most people in iodide deficient areas use unrefined salt that can be effectively supplemented with potassium iodate without added carrier agents or stabilizers. Iodate is more stable under adverse climatic conditions than iodide and does not require stabilizers. It is also less soluble than iodide and less likely to migrate from the bag but is only sparingly soluble in water at low temperatures. However, solutions of up to 40g/L are readily obtainable from manufacturers. Such a solution is sufficient for salt iodization even at iodide levels of 100mg/kg. Potassium iodate breaks down rapidly in the human body and effectively delivers iodide to the thyroid gland for the synthesis of thyroid hormone (Gidey et al., 2015; Milczarek et al., 2013).

Table 2.4: Recommended levels of iodide in salt; µg iodide per kg salt (ppm).

Climate and daily consumption g/person		Factory level		Retail level		Household level
		Bulk	Retail < 2kgs	Bulk	Retail <2kgs	< 2kgs
Warm moist	5g	90	70	80	60	50
	10g	45	35	40	30	25
Warm, dry or cool, moist	5g	80	60	70	50	45
	10g	40	30	35	25	22.5
Cool dry	5g	70	50	60	45	40
	10g	35	25	30	22.5	20

Source; (Andersson et al., 2007; Milczarek et al., 2013)

The Kenya micronutrient survey of 1994 reveal that the household iodized salt use was 90% (Davis T 1994). Estimated daily per capita salt consumption: 5-10g. The Kenya Demographic Health Survey (KDHS) of 2009 estimates that nearly all households in Kenya (98%) are consuming salt with an adequate level of iodide. Other significant findings in the KDHS 2009 include households with no salt at all (urban

4.8%, rural 5.7%); households with non-iodized salt i.e. 0ppm (urban 0.2%, rural 0.2%); households with inadequate iodide content in salt i.e. < 15ppm (urban 1.9%, rural 2.2%) nationally while households with no salt at all (4.7%); households with non-iodized salt i.e. 0ppm (1.5%); households with inadequate iodide content in salt i.e. < 15ppm (0.8%) in Coast region.

Kenya is a major salt producer, of which 85% (235,000 tons per year) comes from the sea. Most is processed in Malindi and Mombasa by five major salt companies, one of which is a refiner. Iodization is carried out by manual or continuous spraying and subsequent mixing is not done by the small packaging companies. Analysis of salt samples in the Multicenter Study by titration showed about 60ppm at the household level, 39ppm at the retail level, and 51ppm at the production level. The higher levels of the household were attributed to excessive iodization by small packaging companies that are poorly monitored. Other studies confirmed wide variations in iodide content of salt, with some samples as high as 8,000ppm (Abuye & Urga, 2000; Gitau, 1988).

Factors affecting access to iodized salt

According to Tapas et al (2010) and Alemu (2015) in a studies on the factors contributing to limited access to iodized salt among selected poor and disadvantaged communities in Ethopia and India; they reported that consumption of iodized salt was higher in urban dwellers than rural dwellers; Hindus than Muslims; higher economic class than lower economic class; those with knowledge on iodide deficiency and iodized salt than those ignorant; those using packaged salt than those using loose salt; those storing salt in closed containers than those storing in the open; and those aware of legislation than those ignorant (Gidey et al., 2015; Tapas, 2010).

Criteria for monitoring progress towards sustainable elimination of iodide deficiency disorders.

The World Health Organization in 2004 came up with a criterion to monitor iodide supplementation programmes. The criterion has targeted indicators as follows: the proportion of households using adequately iodized salt to >90% to ensure adequate salt iodization, proportion of population with urinary iodide levels below 100µg/l and 50µg/l to be <50% and <20% respectively to ensure adequate consumption of iodized salt. To ensure sustainability of the programme at least eight of the following programmatic indicators should be adhered to by each nation:

- An effective functional national body responsible to the government for the national programme for the elimination of iodide deficiency disorders.
- Evidence of political commitment to USI and elimination of IDD appointment of a responsible executive officer for the IDD elimination programme.
- Legislation or regulations on USI to cover human and / or agricultural salt.
- Commitment to assessment and reassessment of progress in the elimination of IDD, with access to laboratories able to provide accurate data on salt and UI.
- A programme of public education and social mobilization on the importance of IDD and the consumption of iodized salt.
- Regular data on salt iodide at the factory, retail and household levels.
- Regular laboratory data on UI in school-age children, with appropriate sampling for higher risk areas.
- Cooperation from the salt industry in maintenance of quality control and a database for recording of results or regular monitoring procedures particularly for salt iodide, UI and, if available, neonatal thyroid stimulating hormone with mandatory public reporting (Andersson et al., 2007).

Iodized bread

Iodized bread has been used effectively in the state of Tasmania in Australia, Newzealand and Russia. The use of iodized breads including all wheat and wheat products in areas where they are widely consumed especially in developed world and urban areas of developing nations has been used as a strategy to supplement iodide with success (Delange et al., 2000; Elnagar et al., 1995; Zimmermann, 2009).

Iodized water

Water has some of the advantages of salt as a vehicle for iodide fortification. Both are daily necessities and thus their iodization will reach the most vulnerable groups – the poor and the isolated. Water fortified at a regular rate with iodide provides the thyroid with a steady iodide supply. Water iodization can be done via various methods:

- Silicone elastomers releasing iodide;
- Iodide added to running water in pipes;
- Iodide added to run-off water;
- manual addition of iodide to standing water.

These methods are effective in smaller communities (Van der Reijden et al.2017, Creswell & Michael 2009).

Iodized oil

Injections of iodized oil are occasionally used in regions of the world where widespread iodized salt use is not possible (De Benoist, 2004). There continues to be an important role for iodized oil, especially in areas where iodized salt is still, difficult to introduce. A variety of iodized oils have been used including most commonly, lipiodol, a poppy seed oil containing 40% iodide per weight. Over the past six or seven decades, iodized oil has been extensively used, initially in Papua New Guinea and thereafter in Africa, China, Europe and Latin America(Eltom, Karlsson, Kamal, Bostrom, & Dahlberg, 1985). Iodized oil has been administered since 1974, initially by injections and subsequently orally, with very few side-effects, including during pregnancy. In the groups most susceptible to the effects of iodide deficiency, women of reproductive age, pregnant women and children less than 2 years, iodide supplements such as iodized oil are recommended where salt iodization coverage is inadequate (Andersson et al., 2007).

In a longitudinal study carried out for 2 years in the Darfur region, western Sudan, 2,316 school children received a single dose of 2 capsules of iodized oil (400mg iodide) orally, and 1,161 school children received 1ml of the same preparation by intramuscular injection (475mg iodide); 2,393 school children served as controls. One year after treatment, goitre prevalence was reduced from 67.0% to 36.0% among the children who had received oral iodized oil and from 71.0% to 42.0% in those who received the injection. The prevalence in the control group did not change. The prevalence in each group was approximately the same 2 years after treatment. Urinary iodide excretion increased after treatment and remained significantly higher than the initial value during the trial (Eltom et al., 1985).

2.9 Monitoring iodide status in a population

Goitre prevalence: Goitre prevalence is tested using palpation of the neck. The person who performs the palpation is an experienced health professional. The goitre classification and epidemiological criteria for assessing the severity of iodide deficiency disorders based on the prevalence of total goitre rate in school children was used based on the recommendation by WHO/UNICEF/ICCIDD (Zimmermann, 2008).

Urinary iodide concentration: 5mls of casual (morning) urine samples are collected in screw cap containers. Samples are stored in an ice-packed cool box before analysis. Iodide concentration in urine samples is determined using Sandell-Kolthoff Reaction (Sandell & Kolthoff, 1937). After determination, the concentration of iodide is recorded in micrograms of iodide per litre of urine and classified according to IDD status.

Table 2.5 Mean urinary iodide levels and diagnostic criteria

Mean urinary iodide levels	Classification
<20 mcg/l	Insufficient, severe ID
20-49mcg/l	Insufficient, moderate ID
50-99mcg/l	Insufficient, mild ID
100-199mcg/l	Adequate, optional
200-299mcg/l	More than adequate
>300mcg/l	Risk of adverse consequences

Blood constituents: Five millilitres of venous blood samples are required for thyroid function tests. Serum samples are immediately prepared by centrifugation and frozen in an ice-packed box before analysis. The serum samples are analyzed for total serum thyroxine (T_4), total serum triiodothyronine (T_3), and thyroid stimulating hormone (TSH) using automatic Enzyme Immunosorbent Assay (ELISA) analyzer. After analysis of the blood constituents, results are interpreted according to the recommended normal ranges in iodide sufficient children and adults by the American Association of Clinical Endocrinologists Guidelines (Vejbjerg et al., 2009).

Table 2.6 Iodide deficiency parameters

Iodide deficiency	none	mild	moderate	severe
Median urine iodide mcg/l	>100	50-99	20-49	<20
Goitre prevalence	<5%	5-20%	20-30%	>30%
Neonatal TSH >5iu/ml whole blood	<3%	3-20%	20-40%	>40%
Cretinism	0	0	+	+

Adopted from WHO, UNICEF, ICCIDD (Zimmermann, 2008)

Coverage of iodized salt at household level: salt samples are collected in plastic capped containers and analyzed for iodide content; using rapid salt testing kits by iodometric titration. After analysis, the salt samples are classified according to their iodide levels as shown in the table below.

Table 2.7 Classification of iodized salt levels

Iodide content	Levels
Non iodinated	<5ppm
Insufficiently iodinated	5-14ppm
Adequately iodinated	15-45ppm
Over iodinated	>45ppm

Adopted from WHO, UNICEF, ICCIDD (Zimmermann, 2008)

CHAPTER THREE

MATERIALS AND METHODS.

3.1 Study site

The study was carried out in the Coastal region of Kenya. The Coast region comprises the former Coast province that is one of the 8 regions in the republic of Kenya. In the 2009 census, it had a population of about three and half million people (KNBS 2010). It borders Eastern region to the north and Rift Valley region to the west, North Eastern region in the North East, the Indian Ocean in the east and the Republic of Tanzania to the South. It covers an area of 83,607 km^2. It has a Coastline of 512km stretching from the Southern tip of the region at Vanga in Msambweni to Kiunga in Lamu in the North Coast. The Coast region is divided into 6 counties comprising of 22 administrative districts.

The counties are: Taita Taveta (comprising Taveta, Mwatate, Wundanyi and Voi subcounties), Kwale (comprising Kinango, Matuga, Lungalunga and Msambweni subcounties), Mombasa (comprising Changamwe, Jomvu, Nyali, Likoni, Mvita and Kisauni subcounties); Kilifi (comprising Kaloleni, Rabai, Kilifi north, Kilifi south, Ganze, Malindi and Magarini subcounties), Tana River (comprising Garsen, Galole and Bura subcounties) and Lamu (comprising Lamu east and Lamu west subcounties).

Table 3.1 Population by county in 2010.

County	Male	Female	Total
Taita Taveta	145,334	139,323	284,657
Mombasa	486,924	452,446	939,370
Kwale	315,997	333,934	649,931
Kilifi	535,526	574,209	1,109,735
Tana river	119,853	120,222	240,075
Lamu	53,045	48,494	101,539
Coast region	1,656,679	1,668,628	3,325,307

Adopted from KNBS 2010 census report

There are about 800 health facilities in the region. Majority of these are Government run facilities offering level I, II and III services. There are 21 sub-county and county hospitals and 1 regional referral hospital.

The morbidity pattern in the Region is mostly influenced by climatic conditions. Common diseases in the region include:- malaria, diarrhoea, diseases of the respiratory system, intestinal worms, skin diseases, anaemia, urinary tract infections/STIs, eye infections and rheumatism. Leading causes of admission include malaria, pneumonia, anaemia, tuberculosis and HIV/AIDS among others. Diseases which are specific to the region include; schistosomiasis and filariasis whose geographical distribution is in the lower Coastal districts of the region (KNBS 2010).

The main inhabitants of the region include Mijikenda, Swahili, Pokomo, Taita and immigrants from other regions in Kenya and also form outside the country.

Various counties and districts in the region differ widely in terms of socioeconomic lifestyles of the people, sociocultural and religious beliefs. Most of these socio-cultural practices affect food production and consumption, and therefore nutritional status. The different counties and districts in the region also have different ecological zones that affect agricultural practices. These factors also affect their nutritional and health status, and levels of poverty and illiteracy.

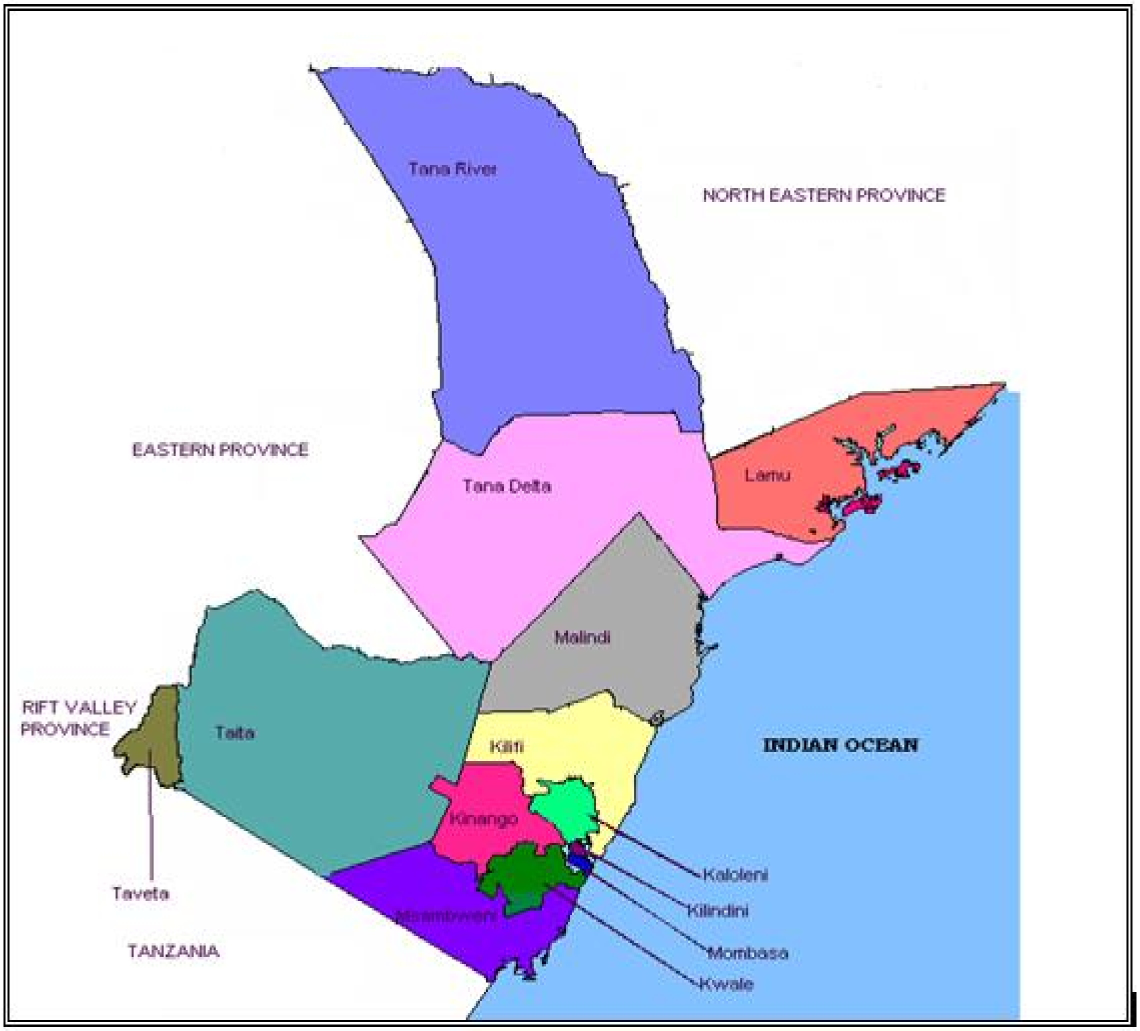

Figure 3.1: Map of Coast Region counties

3.2 Study population

The study population were women who were the household heads or spouse of household head where the head was a man. Information relating to household characteristics, demographics, socio-economic status and iodide food fortification and consumption was collected at household level. Table salt samples were collected for iodide level analysis.

Criteria for inclusion of respondents

a) Women of reproductive age (15 – 49 years).
b) Eligible women respondents who gave consent

Criteria for exclusion of respondents

a) Women working in the household as house helps
b) Women found to be ill during the research period

3.3 Study design.

This was a community based study that employed a cross-sectional study design where the data on household characteristics, demographic profile, socio-economic status, iodide salt fortification and consumption from respondents was collected once. The data was recorded in a questionnaire.

3.4 Sampling procedure

The sampling frame for this study was the enumeration areas (EAs) in Coast region from the 2009 Kenya Population and Housing Census. The EAs were developed through a cartographic mapping exercise conducted between 2007 and 2009 and were used for the 2009 census enumeration. EAs were created utilizing an average of 100 households as a measure of size with lower and upper limits of 50 and 149 households, respectively. The sampling for this study employed a two-stage sampling. Within the region, EAs (clusters) were identified by purposive sampling based on accessibility and then within each selected EA, some households were randomly selected for enumeration using EPI-INFO computer programme. In every household one woman who was eligible was recruited into the study. To each of these persons a questionnaire was administered and a salt sample was obtained from every selected household. The number of clusters selected in a district was dependent on population density.

3.5 Sample size determination

The sample size required was based on the estimated prevalence of iodide deficiency 25% in Kenya based on UIER (M. Andersson et al., 2003; Kulwa et al., 2006), the desired precision of 95%. The Fisher's formula for estimating the minimum sample size for prevalence descriptive studies was used as follows: (Charan & Biswas, 2013).

$$n = \frac{Z^2{}_{\alpha/2}\, p(1-P)}{d^2}$$

Where; $Z_{\alpha/2}$ = area under the curve for normal distribution corresponding to the 95% confidence level

P = the target prevalence = iodide deficiency in school age children in Kenya based on UIER = 25% (WHO & UNICEF 2007)

d = the allowable error = 5%

n = ($(1.96)^2 * 0.25(0.75) / (0.05)^2 = 288.12$

Adjusted to 289 respondents

Recruitment strategy

The recruitment strategy for the study participants included the following activities

- Sensitization of the stakeholders – including the administrators, community leaders.
- Community sensitization
- Listing of the clusters from the KNBS and sampling.
- Listing of households and sampling.
- Consent administration.

3.6 Data Collection

During the study, data was collected using structured questionnaires (Appendix 1). Two hundred and ninety two questionnaires were administered to one respondent in each household. The questionnaires included questions relating to the household socio-demographic characteristics, food consumption, knowledge, practices and behaviours of the respondents living in the selected household. The average iodized salt consumption per person in a month was computed by dividing the amount of iodized salt consumed by a household by the household size. The average consumption of iodized salt per person per day and in a year was computed. A salt sample was collected from every sampled household for iodide level analysis.

Labeling of Questionnaires and Sample Storage

A unique bar-coded number was assigned to each respondent consenting to sample collection. At the time of the sample collection, the bar-coded label with each respondent's identity was affixed to the questionnaire. A matching label was also affixed for salt sample labeled with the sample brand name, collection point and details of district where it was sampled, date of collection and name of person collecting the sample.

Salt sample collection and transportation

Samples of salt used for the main meal during the past 24 hours were collected from two hundred and ninety two households selected for the study. About 25g of salt was scooped with a tea spoon and taken for salt iodide analysis. After recording the brand, quality and expiration date of the selected salt, each sample was put in a plastic container and closed tightly with a screw cap. The samples were stored in the field laboratory within an hour of collection and transported to the analyzing laboratory within forty eight hours.

Analysis of salt iodide

The salt was quantitatively analyzed for iodide using iodometric titration method as described by DeMaeyer et al., 1979. (Appendix 3) (Agrawal, Sunita, & K Gupta, 1999, Demaeyer 1979). The salt was classified according to the iodide levels as; non-iodinated (5ppm), insufficiently iodinated (5 – 14ppm), adequately iodinated (15 – 45ppm) and over iodinated (>45ppm) (ICCIDD et al, 2011)

3.7 Data management and analysis

At the end of every interview the questionnaire was cross checked for verification and reviewed for completeness and correctness in the field prior to departing the household. The data was entered into SPSS computer packages and tabulated. This was followed by data cleaning and verification. The questionnaires and data backup were stored in flash disk and Computer disks kept under lock.

Data analysis was carried out by using descriptive statistics. After the quality of the data collected had been established and the general descriptions for the study variables were obtained, data were analysed using bivariate analysis and significant differences were assessed by comparing the odds ratios with a confidence level of 95% with a significance at $p<0.05$. Multivariate analysis and logistic regression was used to analyse demographic factors contributing to iodide deficiency.

3.8 Ethical considerations

- Informed consent was obtained from the participants who were above 18 years of age and from responsible guardians for those less than 18 years of age. Those under 18 years were asked to accent to participate in the study. (appendix 3)
- Confidentiality regarding the participants' particulars was maintained by restricting access only to the author.
- Data collection procedures did not cause physical harm to the participants.
- The relevant ethical clearance was obtained from the ethical review committee in KEMRI; no. 2183.
- There were no anticipated risks expected to arise from any of the data collection procedures in this study.
- The information collected during the research was not shared with other people except those who were involved in the study. The questionnaires were kept safely by the author and were always under lock. Data on computer was protected using passwords.
- The interviews and specimen collection were carried out in privacy and away from other community members.

Consenting process

The consenting process was carried out by the researcher. The participants were taken through the informed consent form in a language they could understand. They were allowed to ask questions and get clarifications before signing the form to participate in the study. Those who could not append signatures used left thumb prints.

CHAPTER FOUR

RESULTS

4.1 Socio –demographic characteristics of respondents

Location of respondents

The respondents were drawn from all the counties in the Coast region of the republic of Kenya. The number of respondents from each county was estimated based on the total population of each county. The distribution of the respondents is shown in Table 4.1.

Table 4.1 Number of respondents per County

County	No. of clusters	No. of house holds	No. of respondents
Taita taveta	5	50	50
Kwale	5	50	48
Mombasa	8	80	76
Kilifi	9	90	90
Lamu	2	20	20
Tana river	1	10	8
Total	30	300	292

Table 4.1 shows the six counties in the Coast region of Kenya that the study covered and the number of clusters in each County which were proportionate to the population density. In each cluster 10 households were selected and only one respondent interviewed in each household. A total of 292 respondents were interviewed out of the selected 300 giving a response rate of 97.3%.

Age of respondents

Table 4.2 Age of respondents

Age	**Frequency**	
	Number	**Percent**
16 - 19	52	17.8
20 – 29	76	26.0
30 – 39	81	27.7
40 -49	56	19.2
>50	27	9.3
Total	292	100

Table 4.2 indicates that majority (53.7%) of respondents were within the age range of 20-39 years. The mean age of the respondents was 38.6 years. The age range of the respondents was 16 – 72 years.

Marital status of respondents

Table 4.3 Marital status of respondents

	Frequency	
Marital status	Number	Percent
Single	58	20.0
Married	189	64.7
Divorced	21	7.3
Widowed	23	8.0
Total	292	100.0

Majority 189(64.7%) of the respondents were married, 58(20.0%) were single; while those who were widowed and divorced were 8.0% and 7.3%, respectively as shown in Table 4.3.

Religion of respondents

Table 4.4 Religion distribution

Religion	Frequency	
	Number	Percent
Christian	189	64.8
Muslim	71	24.2
Traditional	26	9
Hindu	6	2
Total	292	100.0

As shown in Table 4.4, most 189 (64.8%) of the respondents were Christians by faith followed by Muslims who constituted 24.2% (71) of the total respondents.

4.2 Socio – economic characteristics

Occupation of respondents

Table 4.5 Occupation of respondents

	Frequency	
Occupation	Number	Percent
Formal employment	60	20.7
Self employed	53	18.0
Unemployed	179	61.3
Total	292	100.0

Table 4.5 shows that the 179(61.3%) of the respondents were unemployed and were dependent on peasant farming, those in formal employment were 60 representing 20.7% of the total respondents while self-employed were 53(18%).

Educational level of respondents

Table 4.6 Education level of respondents

	Frequency	
Education level	Number	percent
None	43	14.7
Primary	132	45.3
Secondary	80	27.3
College	31	10.7
University	6	2.0
Total	292	100.0

The results in Table 4.6 show the highest proportion 132(45.3%) of the respondents had attained primary level of education followed by those who had secondary education constituting 27.3%. A sizable number 43(14.7%) had not attained any formal education, 31(10.7%) had attended middle level college while 2% had University level of education.

4.3 Knowledge and practice in respect to iodide

Information on iodized salt

Despite all households having iodized salt for their use, all the respondents demonstrated lack of knowledge on iodized salt. The respondents were not aware that the salt they used was in fact iodized. None of the respondents looked specifically for iodized salt when buying. The packages of the salt used in these households were clearly marked iodized salt. The respondents agreed that the processed iodized salt was universally available throughout the year in the places of purchase.

Knowledge on health benefits of iodide and iodide deficiency

All the respondents in the households interviewed in this study demonstrated complete lack of knowledge on the health benefits of iodide in humans and iodide deficiency disorders.

Salt packaging

The respondents acquired iodized salt from various sources including supermarkets, kiosks, retail shops and markets. All the households had processed salt. The most common brands were Kensalt and Kaysalt. Both brands had iodide levels between 50 – 60ppm as indicated on the packages. The study was able to establish that in all the households visited the iodized salt was well packaged in polyethylene packages.

Storage of salt

Table 4.7 Salt storage methods at home

Storage method	Frequency	
	Number	Percent
Covered container	164	56
In its package	70	24
Open container (salt exposed)	58	20
Total	292	100

Majority of the households (80%), stored their salt covered; i.e. 164(56%) in covered containers, 24% in its package while 20% mentioned that they stored their salt in open containers as shown in Table 4.7.

Salt storage places at home

Table 4.8 Salt storage places at home

	Frequency	
Storage place	Number	Percent
Kitchen	164	56
Store	76	26
Outside	53	18
Total	292	100

Majority of the households 82% stored their salt in dry places i.e. 164(56%) in the kitchen, 26% in the store while 18% stored their salt in wet places (outside the house) as shown in Table 4.8.

Timing of addition of salt to food

Table 4.9 Timing of addition of salt to food

Timing	Frequency	
	Number	Percent
Before start of cooking	47	16
Mid of cooking	182	62.4
Towards end of cooking	32	11
Salt added on dining table	31	10.6
Total	292	100

The majority of the households 182(62.4%) said they add salt to food at the mid of cooking process; 16% add salt to food before the start of the cooking process while 11% add salt to the food towards the end of cooking and 10.6% add salt on dining table as shown in Table 4.9.

Consumption of iodized salt

Table 4.10 Average iodized salt consumption

Number of households	Percent	Estimated iodized salt consumption / person / month (g)	Estimated iodized salt consumption / person / day (g)	Estimated iodized salt consumption / person / year (g)
47	16.1	90 - 150	3.0 – 5.0	1,095.0 – 1,825.0
148	50.7	165 – 225	5.5 – 7.5	2,007. 5 – 2,737.5
70	24.0	240 – 300	8.0 – 10.0	2,920.0 – 3,650.0
27	9.2	315 - 360	10.5 – 12.0	3,825.5 – 4,380.0
292	100.0			

All the households selected in the study had iodized salt. Table 4.10 illustrates that 16.1% consume between 3 – 5g of salt per person per day, 50.7% consume between 5.5g per person per day, 24.0% consume between 8.0 – 10.0g per person per day while 9.2% consume between 10.5 – 12.0g per person per day.

Salt Iodide levels in household salt

A salt sample was collected from each of the households visited analysis of iodide levels. The salt samples were of branded salt from Kensalt and Kaysalt.

Table 4.11 Salt iodide levels

Iodide level (ppm)	**Frequency**	
	Number	**percent**
< 5	96	33.0
5 – 14	119	40.8
15 – 45	54	18.4
>45	23	7.8
Total	**292**	**100.0**

Salt iodide analysis revealed that a majority 119(40.8%) had iodide levels between 5 - 14ppm, (insufficiently iodinated); 33.0% were considered non-iodinated with iodide levels of less than 5ppm; and 18.4% had adequately iodinated salt with levels 15 – 45 ppm. Only 7.8% had over iodinated salt with levels above 45ppm as shown in Table 4.11.

Table 4.12 Association between demographic characteristics and salt iodide levels

	salt iodide levels at household level				
	≥15ppm	<15ppm	OR	95% CI	p-value
Age (years)					
<19	12	40	0.86	0.37-1.98	0.7209
20-29	26	50	0.50	0.24-1.01	0.0516
30-39	22	59	0.69	0.33-1.42	0.3152
≥40	17	66	Ref		
Education level					
None	8	35	0.10	0.03-0.27	**0.000003**
Primary	31	101	1.38	0.61-3.10	0.4373
Secondary	27	73	0.83	0.36-1.93	0.6659
Tertiary	11	26	Ref		
Marital status					
Divorced	4	17	4.25	1.31-13.62	**0.0101**
Widowed	7	18	0.74	0.26-2.16	0.5851
Married	53	137	0.75	0.37-1.49	0.4084
Single	13	45	Ref		
Religion					
Muslim	19	52	0.86	0.46-1.59	0.6226
Traditional	11	15	0.43	0.18-0.99	**0.0439**
Hindu	2	4	0.63	0.11-3.53	0.5913
Christian	45	144	Ref		
Occupation					

Unemployed	41	138	1.57	0.93-2.67	0.0908
Employed	36	77	Ref		

Table 4.12 shows a bivariate analysis for demographic factors associated with iodide deficiency. There was significant association with respondents who were between 20 – 29 years of age (p – 0.0516), illiterate (p - 0.000003), divorced (p – 0.01) and traditionalists (p – 0.0439). A total of 292 participants were enrolled in the study with the mean age of 35 + (10 SD) years ranging between 16-72 years. Of the 292 participants, 189 (64.7%) were Christians, 71(24.3%) were Muslims, 26 (8.9%) were traditionalist and 6 (2.1%) Hindu. About 65% were married, 61% were unemployed and 14.7% were not educated.

Table 4.13 Association between salt storage and cooking practices and salt iodide levels

	salt iodide levels at household level				
	≥15ppm	**<15ppm**	**OR**	**95% CI**	**p-value**
Salt container					
Open container	23	35	0.08	0.05– 0.15	**0.000001**
Covered container	54	180	Ref		
Place of storage					
Moist/wet places	28	24	0.22	0.12-0.41	**0.000001**
Dry places	49	191	Ref		
Time salt is added					
Before Cooking	9	38	3.05	1.10-8.44	**0.02863**
Mid of cooking	34	148	3.14	1.41-7.03	**0.00390**
End of cooking	21	11	0.38	0.14-1.05	0.05929
On dining table	13	18	Ref		

Table 4.13 shows a bivariate analysis for salt storage factors associated with iodide deficiency. There was significant association with open containers (p – 0.00001), moist places (p -0.000001) and length of time salt is added during cooking. In the bivariate analysis, having formal education (OR=3.22, 95%CI: 0.03-0.27, p=0.0436), covering of salt containers (OR=2.19, 95%CI: p= 0.0103) and storing salt in dry places (OR=0.22, 95%CI: 0.12-0.41, p=0.000001).were associated with availability of adequately iodized salt at household level. There was no association between respondents age with availability of adequately iodized salt.

Salt iodide levels in each county

Table 4.14 Mean salt iodide levels in each county

County	Number of respondents	Mean salt iodide levels (ppm)	SD
Taita taveta	50	9.32	3.007
Kwale	48	11.12	4.773
Mombasa	76	21.45	7.268
Kilifi	40	13.45	6.009
Malindi	50	18.48	5.319
Lamu	20	10.60	3.686
Tana river	8	8.40	5.328
Total	292	12.72	4.691

Table 4.14 shows the mean salt iodide levels in each county. As illustrated Taita Taveta, Kwale, Kilifi, Lamu and Tanariver have mean salt iodide levels below 15ppm, while Mombasa and Malindi have mean salt iodide levels above 15ppm. The mean salt iodide level for the Coast region of Kenya is 12.72ppm (SD = 4.691), with a range of 8.40 – 21.45ppm.

CHAPTER 5

DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 Discussion

5.1.1 Socio-demographic characteristics of the respondents

The survey was carried out for a period of one year between September 2012 and August 2013. A total of 292 respondents were recruited for the study. The number of households selected in each county was dependent on the population density. The study respondents depict a mix of characteristics in age, marital status and religious affiliation.

5.1.2 Proportion of households consuming iodized salt in coastal region.

Prevention of iodide deficiency is possible if more than 90% of the households consume adequately iodized salt and must be granted (ICCIDD 2011). The study showed that 26.3% of the households had adequately iodized salt at household level. This concurs with a study carried out in Ethiopia by Hailay et al (Hailey et al 2013). This is very low compared to a study in India where 51% of households had adequately iodized salt (Bohac 2009). This can be attributed to availability and accessibility of iodized salt in the market, legislation and policies to fortify salt with iodine, regular follow ups and monitoring utilization of iodized salt. Among analyzed variable education level, place of storage and salt container was associated with iodide deficiency. In this study, all the households had processed well packaged iodized salt branded salt (Kensalt and Kaysalt). According to Davies 1994 and Tapas et al 2010 in a study on the factors contributing to limited access to iodized salt among the poor and disadvantaged in North 24 Parganas District of West Bengal, India; it was demonstrated that consumption of iodized salt was higher in urban dwellers than rural dwellers; Hindus than Muslims (Davies, 1994,Tapas et al. 2010). In this study however consumption of iodized salt was noted to be uniformly acceptable and there were not difficulties to access of iodized salt even in rural areas. The availability of iodized salt in all households was uniform; it was not shown to be affected by age of respondents, marital status, residence (rural or urban), religion or occupation of the head of the households. This may be due to the regulation of universal salt iodization programme.

5.1.3 Levels of iodide in salt at the household

Among the households 73.8% had inadequate salt iodide levels of less than 15ppm. 18.4% had adequate salt iodide levels between 15 – 45ppm while 7.8% had over iodinated salt. The mean salt iodide level for the Coast region of Kenya is 12.72ppm (SD = 4.691, p=0.005), with a range of 8.40 – 21.45ppm. According Gitau1988 and KNBS 2010, 1.5% of households in Coast region had non-iodized salt (0ppm) while 0.8% of households had inadequately iodinated salt (< 15ppm). In this study all the households had iodized salt though a substantial proportion had inadequately iodinated salt (Gitau, 1988).

The salt iodide levels differ between households probably influenced by practices that lead to losses of iodide from salt before consumption. The salt iodide levels at manufacturing level are 50 – 60ppm. The post production loss is estimated at > 35ppm (70%) in 73.8% of households with salt iodide levels < 15ppm. This is slightly more than the losses demonstrated by tapas et al 2010 in India and Dawit et al in Ethiopia studies respectively. Going by the study on stability and retention of potassium iodide in salt by Adejo 2013 in Nigeria and Toks et al 2004 in Kenya that confirmed retention of iodide of 90% from consumer to manufacturer it means that the loss of iodide is mainly at the household level (Adejo & Enemali, 2013; Diosady et al., 2006)(Toks et al 2004).
The results of this study demonstrated an improvement from what Muture et al 1994 demonstrated in a Kenyan study; where 15.9% samples complied with the legislation of 168.5g/kg. Five samples had exceptionally high iodate; a mean of 8147.1g/kg. The mean iodate content of all samples analysed was 151 mg/kg. Uniformity of iodation was lacking as indicated by high standard deviations. Two manufacturers had iodate content

complying with the minimum 168.5mg/kg required by the legislation (Muture et al 1994).

5.1.4 Risk factors of iodide deficiency in Coast region of Kenya.

Risk factors for iodide deficiency are those factors that lead to low iodide in diet. In this study some of these factors include: low salt consumption; below 5g/day. The iodide levels in salt at the manufacturer is estimated for salt consumption of between 5 – 10g//day. Consumption of salt with iodide level less than 15ppm (in 73.6% of respondents). This is salt classified either as non-iodinated or inadequately iodinated. Other factors that may contribute to iodide deficiency are illiteracy (p-0.00003, 95%CI), divorced women heading households (p-0.01, 95%CI), traditional religious followers (p-0.04, 95%CI), salt storage in open containers (p-0.00001,95%CI), salt storage in moist/wet places (p-0.00001, 95%CI) and adding salt to food early during cooking; before cooking (p-0.03, 95%CI), and mid of cooking (p-0.004, 95%CI).

According to Tapas et al 2010 in a study on the factors contributing to limited access to iodized salt among the poor and disadvantaged in North 24 Parganas District of West Bengal, India; it was demonstrated that consumption of iodized salt was higher in the people in higher economic class than lower economic class. In this study the disparity in iodized salt consumption between socioeconomic class classes was not obvious. Financial constraints should not be a hindrance to access of iodized salt since it's a cheap and affordable food commodity going at an average cost of ten Kenya shillings for a quarter a kilogramme (Davies, 1994; Gitau, 1988).

According to Tapas et al 2010 in a study on the factors contributing to limited access to iodized salt among the poor and disadvantaged in North 24 Parganas District of West Bengal, India it was demonstrated that consumption of iodized salt was higher in those with knowledge on iodide deficiency and iodized salt than those ignorant, those aware of legislation than those ignorant (Tapas et al. 2010). The Kenya Demographic Health

Survey (KDHS) of 2009 estimates that nearly all households in Kenya (98%) up from 90% in 1994 were consuming iodized salt (Davies, 1994, KNBS 2010).

Education increases awareness and informed decision making of individuals. The study showed respondents with no education were significantly associated with consumption of inadequately iodized salt. This consistent with studies done in Pakistan and Iraq where household members with tertiary education used iodized then those illiterate. Fortification of salt with iodine is not enough to alleviate iodide deficiency hence education should play a role in communicating information about importance of consuming adequately iodized salt to the population (Imdad et al 2008; Ebrahim 2012).

All the clusters visited during the survey had a supply of well packaged iodized salt. According to Tapas et al 2010 in a study on the factors contributing to limited access to iodized salt among the poor and disadvantaged in North 24 Parganas District of West Bengal, India it was demonstrated that consumption of iodized salt was higher in those using packaged salt than those using loose salt (Tapas et al. 2010). KDHS 2009 reported that about 4.7% of in coast region of Kenya had no salt at all (KNBS 2010). Compared to the report of KDHS, it may seem that the situation has improved since all households visited had iodized salt. The laws of Kenya require that all table salt should be iodized and forbids consumption of non-processed salt. Since the Coast region of Kenya is a producer of salt, the salt available is iodized to the required levels. As a result communities in the region have access to iodized table salt.

According to Tapas et al in a study on the factors contributing to limited access to iodized salt among the poor and disadvantaged in North 24 Parganas District of West Bengal, India it was demonstrated that consumption of iodized salt was higher in those storing salt in closed containers than those storing in the open (Tapas et al. 2010).

A study done by Dawit et al, 2010 to assess the post-production losses in iodide concentration of salt in Northern Ethiopia; showed the average decrease in iodide concentration of salt samples from the production to the retailer level was 29% and 50%

from the retailer to the consumer level. On average, the iodide concentration was reduced by 57% from the production to the consumer level. Potassium iodate in salt is not very stable and can easily be lost by oxidation to iodine if the iodized salt is subjected appreciably to any of the following conditions: moisture in the salt, humid or excessively aerated environment, exposure to sunlight, exposure to heat, acid reaction in the salt or presence of impurities (Dawit et al 2010). 10.6% of the respondents add salt to food at the dining table, the rest add salt during cooking; 11% of these towards the end of the cooking process. High humidity resulted in rapid loss of iodide from salt iodized with potassium iodate, ranging from 30% to 98% of the original iodide content. Solid low-density polyethylene packaging protected the iodide to a great extent. High losses occur from woven high-density polyethylene bags, which are often the packaging material of choice in tropical countries (Dawit et al 2010; ICCIDD 2011).

In the study 78.4% of households expose salt to prolonged heating at high boiling temperatures during cooking as they add salt early in the beginning to mid of cooking process. Tapas et al, Dawit et al and Gidey et al demonstrated that prolonged cooking of iodized salt is one of the factors contributing to iodide losses from salt before consumption.

5.2 Conclusions

- All households recruited into the study consume iodized salt
- Majority of households in the study (73.6%) consume salt with low iodide levels.
- Some of the risk factors contributing to iodide deficiency include: low salt consumption, low iodide in salt, illiteracy, divorced women as household heads, traditional religious followers, exposure of salt to the environment and heat during cooking.

5.3 Recommendations

- Initiate health education programmes to improve salt consumption, iodide preservation through proper storage and cooking methods.
- Store iodized salt in closed containers and in closets at home if removed from its package.
- Adopt proper cooking methods that preserve iodide in salt by avoiding over heating the iodized salt.
- Expand the iodide supplementation methods; consider programmes like iodized water, iodized wheat products, iodide injections, oral annual doses of iodide, iodized oils.
- Research is required on the role of goitrogens in iodide deficiency in the Coast region.

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APPENDICES

APPENDIX 1

ENGLISH QUESTIONNAIRE.

Factors contributing to iodide deficiency.

Questionnaire serial no.______________

A) **Interviewer visits**

Name of interviewer ____________________

First visit date _________ outcome () Last visit date __________ outcome ()

Outcome codes: 1. Completed 2. Nobody to be interviewed during visit 3. House abandoned 4. Interview postponed 5. Declined 6. House destroyed 7. House not found 8. Any other ___________________ (mention)

B). **Address**

District______________Location___________Sublocation___________

Cluster number ______________Household number ________________

C). Socio-demographic characteristics

1).What is your age _______

2).Marital status? i. Single () ii. Married () iii. Divorced ( ) iv. Widowed ()

v. other () mention _______________

3). What is your religion? .i Christian () ii. Muslim () iii. Traditional () iv. Hindu ()

v. Other () mention ____________________

D)Socio – economic factors

1).What is your occupation? i. Employed () ii. Self employed () iii. Unemployed ()

iv. Others () mention _______________

2). What is your level of education? i. Primary () ii. Secondary () iii. College () iv.university () v. None () vi. other () mention _______________

E)Knowledge, attitude, and practices on micronutrients

1). Do you know any micronutrients and minerals required in the body?

i.yes() ii.No() iii.I don't know()

Please mention a few - :1.______________2.________________ 3. ____________

2).What is the role of these micronutrients and minerals in the body?

1.________________ 2. ______________________ 3. ______________

3). Are there any food taboos that you are aware of? i. Yes () ii. No () iii.I don't know ()

Please give specific examples -: 1_______________2. _______________3___________

4). Are there foods children are not allowed to eat? 1. Yes () 2. No () 3. I don't know ()

Please give specific examples -: ________________ 2. _____________ 3. _________

5). Are there any foods women are not allowed to eat? i. Yes () ii. No () iii. I don't know () Please give specific examples -: 1______________2_______________3__________

6). What do you add to food /vegetables during cooking? i.Salt ii. Milk iii. Coconut iv. Ash v. Curry powder vi. other (mention) __________

7). Do you have any foods available here that are a source of the mineral iodide?

i.Yes () ii. No () iii. I don't know () Please give specific examples -: 1_____________2______________3________

F)Salt fortification

1). Have you ever heard about iodized salt? i. Yes () ii. No () ii. I don't know ()

If yes, mention the source i. Health care worker () ii. Radio / television () iii. Newspapers () iv. Neighbours () v. Relatives () vi. other (mention)__________

2). what benefits do people gain by using iodized salt?

1___________________2______________3_______________________

3). what health effects are associated with iodide deficiency?

i.Goitre () ii. Cretinism () iii. Mental retardation () iv. I don't know

v other (mention) _____________________

4). Where do you buy the salt you use in your food? i. Kiosk () ii. retail shop () iii. wholesale shop () iv. Supermarket () v. Market () vi. on market days () vii. I don't know viii. other (mention) _____________________

5). Is the salt you buy raw or processed? i. Raw () ii. Processed () iii i don't know ()

6). Which salt brand do you buy often?

i.Brand name _______________ii. No brand name ____________ iii. I don't know

7). How is the salt packaged i. Packed () ii. No packaging iii. Other (mention) ____

8). How often do you buy salt? i. Once a week () ii. Once in 2 weeks iii. Once a month iv. Once in 2 months v. Once in 3 months vi. Other mention_________________

9). How much salt do you buy and at what cost?

i. 250 gms ksh _________ ii. 500 gms ksh ______________ iii. 1 kg ksh _____

iv. 5 kgs ksh _____________ v. Other specify_______________________

10). How much salt do you use in one month? ___________ kgs.

11). Do you know the salt you use is iodized? i. Yes() ii. No () iii. I don't know()

12). Do you look for iodized salt when buying? i. Yes() ii. No() iii. I don't know ()

13). Is the salt package marked ''iodized salt''?i. Yes() ii. No()iii.I don't know()

14).How available is iodized salt here? i. Always available () ii. Never been available () iii. Has been unavailable in past one month () iv. has been unavailable for the past v month () vi. has been unavailable for the past 1 year () vii. Other (mention) _________

15). Where do you store the salt? i. Kitchen() ii. Store () iii. Outside () iv. other (mention) ______________

16). How do you store your salt? why? ___________________________

i.Covered container () ii. open container () iii. in it's package () iv. on the floor open () v. on the floor covered() vi. Other __________

17). Which domestic animals do you rear? i. Cows() ii. Bulls () iii. Goats () iv. Sheep v. Camels () vi. Chicken () vii. None () viii. others (mention) __________

18). Do you feed the animals with this salt? 1. Yes () ii. we feed them on different salt() iii.We don't feed them on salt ()

19). At what point do you add salt to food during cooking i. When raw / before we start cooking () ii. in the mid of the cooking () iii. towards the end () iv. no salt added () v. at the table during eating () vi. Other ___________

G) **Salt sample collection – 50 gms sample**

1). was sample collected? (affix pre printed label here and on sample collected)

i. Yes () ii. No salt in household () iii. no, refused to give sample()

2). what is the type of table salt sampled?

i.Brand (specify)______________ ii. Brandless salt () iii. Other labeled type () iv. Don't know()

3). expiry date ____________________________

APPENDIX 2

SWAHILI QUESTIONNAIRE

Factors contributing to iodide deficiency.

Questionnaire serial no.______________

A). **Ziara za muuliza maswali**

1. Jina la Muuliza Maswali _____________________

2. Ziara ya kwanza tarehe _________ matokeo () Ziara ya mwisho tarehe _______ matokeo ()

3. Visimamizi Matokeo:

i. Yalimalizwa

ii. Hapakuwa na mtu nyumbani ama hapakuwa na mtu awezaye kujibu maswali wakati ilipotembelewa

iii. Wote hawakuwepo nyumbani kwa mda mrefu

iv. Yameahirishwa

v. Walikataa

vi. Nyumba imehamwa ama pahala hapa si nyumba ya kuishi watu

vii. Nyumba ilivunjwa –

viii. Nyumba haikuonekana

ix. Lengine____(Litaje)

4). Mahali wilaya _______________mtaa____________mtaa mdogo____________

Cluster number_______________nambari ya nyumba _________________

B) Socio-demographic characteristics

1). Je (Jina) una umri gani _______

2). Je (Majina) kwa sasa ameoa/ameolewa? i oa/olewa ama kuishi pamoja. ii Talakiwa ama wameachana iii mjane iv Hajaolewa ama kuishi pamoja

3). Je wewe unaabudu dini gani? i. Mkristo () ii. Muislamu () iii. Kienyeji () iv. Mhindu () v. Nyingine () taja __________________________

C) Socio – economic factors

1).unafanya kazi gani kujikimu kimaisha? i. Kuajiriwa () ii. Kujiajiri () iii. Sina kazi () iv. Nyingine () taja _____________________

7). Je uko na kiwango gani cha masomo? i. Msingi () ii. Sekondari () iii. Chuo anuai () iv.chuo kikuu () v. Sijasoma () vi. Nyingine () taja ______________________

D) Knowledge, attitude, and practices

1). Je unajua kuhusu lishe zinazo hitajika mwilini kwa kiwango kidogo i Ndio () ii La () iii Sijui () kama ndio taja : 1._______2._____ 3. ____________

2). lishe na madini vina faida gani mwilini?1.__________ 2. _____ 3. ________

3). Je mna vizuizi ama miiko yoyote kuhusu vyakula katika jamii hii yenu? i Ndio () ii La () iii Sijui ()

4) Vizuizi ama miko hii ni gani? 1_____________2. _______________3___________

5). Je Kuna vyakula aina Fulani ambavyo watoto hawaruhusiwi kuvila? i Ndio () ii La () iii Sijui ()

6) Vyakula hivi ni gani? -: ________________ 2. _____________ 3. _________

7). Je kuna vyakula aina fulani ambavyo wanawake hawaruhusiwi kuvila? i Ndio () ii La () iii Sijui ()

8) Vyakula hivi ni gani? 1______________2_______________3____________

9). Mpikapo mboga zenu za majani, huwa mnaongeza nini ndani ya mboga hizo?

i. Chumvi () ii . Maziwa () iii. Tuwi () iv. Jivu () . v Bizari () vi Lengine (taja) __________

10). Je unajua aina ya vyakula vinavyo patikana na kutumiwa katika eneo hili lenu ambavyo vina aina ya lishe ya madini ya iodide kwa wingi. I ndio () ii La () iii Sijui ()

11) Vyakula hivyo ni gani -: 1_____________2______________3________

E) Salt fortification

1). Umepata kusikia kuhusu chumvi iliyo ongezwa iodide? i Ndio () ii La () iii Sijui ()

2) Kama ulisikia, ulisikia kutoka kwa nani? i Mfanyi kazi ya afya () ii Redio / runinga () iii Jirani () iv Mwanangu () v gazeti() vi Mwingine (Taja) ______________________

3). Kuna manufaa gani kwa watumiaji chumvi iliyo ongezwa iodini?

i___________________ii______________iii______________________

4). Je ukosefu wa iodide mwilini una madhara gani? i Goitre () ii. Cretinism () iii. Akili punguani () iv. Sijui () v. Lengine (taja) ________________________

5). Je nyinyi hununua chumvi mnayoweka kwa chakula wapi?

i. Kutoka kwa duka lililo katika eneo letu
ii. Duka lililoko mjini karibu na kwetu
iii. Duka la jumla kijijini mwetu
iv. Kutoka kwa soko la kila wiki
v. Kwengine (Taja)
vi. Sijui

6). Chumvi mnayonunua huwa imesagwa? .i Ndio () ii. La ()

7). Ni chapa gani ya chumvi ya chakula ninyi hununua mara nyingi? i Chapa (Taja) _____________________ ii Chumvi haina chapa iii Sijui

8). Chumvi mnainunua ikiwaje (ikilazimika weka alama kwa zaidi ya jibu moja) i Ya kupima (haina pakiti) ii. Iliyo katika pakiti iii. Nyingine (Taja)…………………………

9). Mnanunua chumvi kiasi gani kwa bei gani? i. 250 Gms Ksh _________ ii. 500 Gm ksh ______________iii. 1 kg Ksh _____________iv 5 kgs Ksh _____________

10). Mnatumia chumvi kiasi gani kwa mwezi? ___________ kgs.

11). Je unajua kama chumvi unayo nunua mara nyingi imeongezwa iodide? i. Ndio () ii. La () iii Sijui ()

12). Je huwa unatafuta/uliza chumvi iliyo ongezwa iodini uendapo kununua chumvi ya kutumiwa nyumbani? i. Ndio () ii La () iii Sijui ()

13). Je pakiti iliyo na chumvi mnayotumia kwa chakula inaonyesha iodini? i. Ndio () ii La () iii Sijui ()

14). Ni lini wakati wa mwisho ulipoenda kununua chumvi iliyo ongezwa iodide na ikawa haipatikani?

i. Yapatikana kila mara
ii. Haijapatikana wakati wowote.
iii. Haijapatikana katika mda wa mwezi mmoja uliopita.
iv. Haijapatikana katika mda wa miezi sita iliyopita.
v. Haijapatikana kwa mda wa mwaka mmoja ulio pita
vi. Lingine (Taja

15). Chumvi huwa mnaiweka wapi? i. Jikoni () ii. Chumba cha stoo (). Iii Inje ya nyumba () iv. Kwingine (Taja) ________________________

16). Chumvi huwa mnaiwekaje? i. Katika chombo chenye kifuniko () ii. Katika chombo kisichokuwa na kifuniko () iii. Katika mfuko huohuo/pakiti hiyo hiyo ilimonunuliwa chumvi () iv. Twaiweka sakafuni (ikiwa wazi) () v. Twaiweka sakafuni (ikiwa imefunikwa) vi. Kwengine (Taja) ________________________

17). Je mna aina gani ya mifugo kwenu nyumbani? i . Ng'ombe () ii. Ng'ombe dume (). iii. Mbuzi () vi. Kondoo () v. Ngamia () vi. Kuku () vii. Hatuna mifugo () viii Wengine (Taja) __________________

18). Je huwa mnawapa mifugo hao chumvi hiyo? i. Tunawapa chumvi hiyo () ii. Tunawapa chumvi nyingine tofauti () iii . Hatuwapi chumvi yoyote ()

18). Mnapokuwa mnapika, mnaongeza chumvi kwa chakula wakati gani?

i. Chakula kikiwa kibichi, kabla ya kuanza kupika
ii. Katikati ya upishi unapoendelea
iii. Chakula kinapoendelea kuiva
iv. Hatuongezi chumvi yoyote
v. Sijui

APPENDIX 3:

CONSENT FORMS

Research title: Factors contributing to iodide deficiency in Coastal region of Kenya.

Key researcher: Kazungu B. Kahindi. ITROMID

Introduction.

I work with the Ministry of Health – Kenya. I'm currently a student in ITROMID – JKUAT at KEMRI – Nairobi. I'm conducting a study on factors contributing to iodide deficiency Coast Region; so that the information can be used to put in place programmes that will help solve this problem. I hope that the data I collect will help in identifying solutions that will help reduce iodide deficiency in the region.

Before you decide whether to participate in the study, there is some information you need to know. This form tells you about this study; you can ask any questions you have at any time.

Being in the study is your choice.

Before you learn more about the study, it is important to know that;

- Your participation in this study is voluntary
- You may decide not to answer any question, give any specimen or even withdraw from the study at any time

Purpose of the study

The aim of this study is to provide us with information on various factors that contribute to iodide deficiency in Coast region. The study will particularly seek to determine the socio-demographic characteristics of the respondents, the coverage of iodized salt consumption, the levels of iodide in salt consumed in households and factors that contribute to loss of iodide from salt in Coast region. This will be done through administration of questionnaires and collection of household salt specimen for analysis.

Study groups

The study will involve women of reproductive age whether pregnant or non pregnant.

Procedures

If you agree to participate in the study by signing at the end of this form , you will answer to a questionnaire and provide us with a salt specimen.

Precautions

There are no expected complications arising from the study procedures.

Data security and confidentiality

All the information gathered through this research process will be used in confidence for this purpose only. Any information relating to your personal identity will remain confidential. Names will not be cited in any reports. You will receive a copy of this consent form. No one will have access to this interview information except the researchers.

New findings

The results of this study will be disseminated to the relevant ministry for the purpose of instituting interventions to prevent iodide deficiency.

Benefits of the study

By participating in this study you will get to share knowledge on iodide deficiency and hence be able to prevent it.

Costs to you

There is no cost to you for participating in this study.

Problems and questions

If you have any questions, you are free to contact Kahindi Kazungu on 0733707367.

Your rights as a study participant.

This research has been reviewed and approved by the ERC in KEMRI, to ensure that all your rights shall not be violated.

Statement of consent and signature.

If you have read the informed consent, or had it read and explained to you and you understand the information and voluntary agree to participate in this study; you are required to confirm participation by signing below.

- I have been given the chance to ask any questions I had and I'm content with the answers to all my questions.
- I know that my records will be kept confidential and that I may leave this study at any time.
- The name and phone number of the contact person in case of emergency has been given to me.
- I agree to take part in this study as a volunteer, and will be given a copy of this informed consent form to keep.

Participant name ……………………………………………….

Signature ……………………and date ……………..

Study staff name ……………………………………………….

Signature ……………………and date………………

May I begin the interview now?

SIGNATURE OF INTERVIEWER: ______________________

DATE: __ __ / __ __ / __ __ __ __

DD / MM / YYYY

APPENDIX 4:

SALT IODIDE ANALYSIS MODULE.

Salt iodate analysis principle.

The iodide content of the iodated salt samples is measured using an iodometric titration method where the reaction mechanism can be considered in two steps:

1**. Liberation of free iodide from salt**

Addition of sulphuric acid (H_2SO_4) liberates free iodide from the iodate in the sample. Excess Potassium Iodide solution is added to help solubilize the free iodide which is quite insoluble in pure water under normal conditions.

2. **Titration of free iodide with thiosulphate**

Free iodide reacts with the thiosulphate in the titration step. The amount of thiosulphate used is proportional to the amount of free iodide liberated from the salt.

Starch is added as an external indicator in this step. It reacts with the free iodide to produce a blue colour. During titration, the loss of the blue colour towards the end of titration indicates that all the free iodide has been consumed by the thiosulphate.

Procedure

- Weigh 10gm of the salt sample into 250ml Erlenmeyer flask.
- Add approximately 30mls distilled water and swirl to dissolve the sample.
- Add water to make up volume to 50mls.
- Add 1ml of 2N sulphuric acid followed by 5mls of 10% KI and swirl to mix. The solution should turn yellow if iodide is present.
- Put the samples in a dark place for 10 minutes.
- Titrate with 0.005N $Na_2S_2O_3$ until the solution turns pale yellow.
- Add approx. 2mls of 1% starch indicator. Solution turns dark blue
- Continue titration until the solution becomes colourless.
- Record the volume of the thiosulphate used

Calculation of results

The thiosulphate volume used is related to the Iodide and Potassium iodate in the salt sample by the following formulae:

Iodide (mg)/Kg salt=Volume (mls) x 10.58

Potassium Iodate (mg) /kg salt =Volume (ms) x17.83

Ref. (Agrawal et al., 1999, DeMaeyer, Lowenstein and Thilly (1979)

APPENDIX 5

TRANSCRIPT

APPENDIX 6

SCIENTIFIC STEERING COMMITTEE APPROVAL

K.E.M.R.I. RECEIVED 10 APR 2012 P.O. Box 20752-00202, NAIROBI. CENTRE FOR PUBLIC HEALTH RESEARCH

KENYA MEDICAL RESEARCH INSTITUTE

Centre for Clinical Research, P.O. Box 20778, 00200, NAIROBI Kenya
Tel: (254 02 2726781, 254 02 2722541, 254 02 2713349, 0722-205901, 0733-400003 Fax 254 02 2720030
Email: ccr@kemri.org Website:www.kemri.org

ESACIPAC/SSC/ 100233 **5th April, 2012**

Kazungu Kahindi

Thro'
Director, CPHR
NAIROBI

Forwarded
10/04/2012

REF: SSC No. 2183 (Revised) – Factors contributing to Iodide deficiency in Coast Province of Kenya.

I am pleased to inform you that the above mentioned proposal, in which you are the PI, was discussed by the KEMRI Scientific Steering Committee (SSC), during its **189th** meeting held on **3rd April, 2012** and has since been approved for implementation by the SSC.

Kindly submit 4 copies of the revised protocol to SSC within 2 weeks from the date of this letter i.e.19th April, 2012 for onward transmission to ERC office.

We advise that work on this project can only start when ERC approval is received.

Sammy Njenga, PhD
SECRETARY, SSC

APPENDIX 7

APPROVAL OF SUPERVISORS

OFFICE OF THE GRADUATE
RECEIVED
11 MAR 2016
PROGRAM COORDINATOR
ITROMID

JOMO KENYATTA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY

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FAX: 254-067-52164/52030

REF: BPS/TM310-1290/2010 **4th February, 2016**

KAZUNGU BONIFACE KAHINDI
C/o SPH
JKUAT

Dear Mr. Kazungu,

RE: APPROVAL OF MSc. RESEARCH PROPOSAL AND SUPERVISORS

Kindly note that your research proposal entitled: **"Factors contributing to iodide deficiency in Coast Province of Kenya"** has been approved. The following are your approved supervisors:-

1. Mr. Charles Mbakaya
2. Prof. Anselimo O. Makokha

Yours sincerely

PROF. MATHEW KINYANJUI
DIRECTOR, BOARD OF POSTGRADUATE STUDIES

Copy to : Dean, SPH

/sn

APPENDIX 8

THESIS SUBMISSION APPROVAL

OFFICE OF THE GRADUATE
RECEIVED
2? JUN 2016
PROGRAM COORDINATOR
ITROMID

JOMO KENYATTA UNIVERSITY
OF
AGRICULTURE AND TECHNOLOGY
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REF: BPS/ TM310-1290/2010 **8th June, 2016**

Boniface Kahindi Kazungu
C/o SPH
JKUAT

Dear Boniface

RE: **APPROVAL OF YOUR INTENT TO SUBMIT MSC. THESIS FOR EXAMINATION**

We are in receipt of your letter of intent to submit your MSc. thesis for examination.

This is to inform you that your request **has been approved**. It is a requirement that you clear with all the relevant departments/sections of the University and forward the duly completed Clearance Form to the BPS office to enable us processes your thesis for examination.

The Clearance Form is obtainable from the Office of the Director, Board of Postgraduate Studies.

Yours sincerely

PROF. (ENG) G. N.MANG'URIU
DIRECTOR, BOARD OF POSTGRADUATE STUDIES

Dean, SPH

APPENDIX 9

PUBLICATION

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FACTORS CONTRIBUTING TO IODIDE DEFICIENCY IN COAST PROVINCE OF KENYA

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2 Kenya Medical Research Institute, Nairobi, **KENYA**

ABSTRACT

Background: Iodide deficiency has serious effects on body growth and mental development. Iodide deficiency disorders are major public health problem in several areas of the world. At least 350 million Africans are at risk of iodide deficiency and are at risk of its complication. In Kenya, iodide deficiency was estimated at 36.8% and 50.7% in the Coast region. This study assessed factors contributing to iodide deficiency in coast region.
Methods: A cross-sectional study was carried out among 292 households in coast region using pretested and structured questionnaires. Multistage sampling technique was used; in the first stage clusters were selected using simple random sampling, and then households were selected using systematic random sampling technique. Data were entered, cleaned and analyzed using SPSS version 21 software. Bivariate analysis was performed to check on association at $p < 0.05$.
Results: About 26.2% of the respondents utilized adequately iodized salt, 80.1% of salt containers had a cover, and 82.2% stored in dry places. Around 22.6% of the respondents add salt at the end of cooking and 78.4% in the early beginning and end in the middle of cooking. Iodide deficiency was associated with lack of education (OR=3.22, 95%CI: 0.03-0.27, p=0.0436), salt container without cover (OR=2.19, 95%CI: p= 0.0103) and moist/wet storage place (OR=0.22, 95%CI: 0.12-0.41, p=0.000001).
Conclusion: Availability of adequate iodized salt at household level was very low when compared to the WHO recommended levels to prevent iodide deficiency
Keywords: Iodide levels, iodized salt, households.

INTRODUCTION

Iodide is necessary for the synthesis of thyroid hormones that regulate growth, development and metabolism. Inadequate intake can result in impaired intellectual development and physical growth [1]. Iodide deficiency is thought to be a public health problem in a community if goitre is detected in more than 5% of the school-age population. Prevalence of greater than 30% means that the deficiency is severe. According to iodide status data collected between 1993 to 2003 in 126 countries, World Health Organization (WHO) estimates that in 54 countries the population has insufficient iodide intake as indicated by a median urinary iodide (UI) below 100µg/l. These countries are classified as iodide deficient: one country is severely deficient, 13 are moderately deficient and 40 mildly deficient. In 43 countries, the population have adequate iodide intake with a median UI between 100 and 199µg/l. Iodide status of these countries is considered as optimal. In Kenya the prevalence of iodide deficiency was estimated to be about 36.8% and 50.7% in Coast region in sentinel surveys done by assessment of urinary iodide levels in 2006. Iodized salt programs are decreasing iodide deficiency in many regions in the world. However; this reduction is offset by apparent increases in other regions, where public health officials are now aware of the problem because of increased surveillance [1, 2]

Iodide deficiency, with endemic goitre as its main clinical manifestation and brain damage and irreversible mental retardation as major public health consequences, is part of the history of the world and Kenya in particular. All regions of Kenya have experienced this health and socioeconomic scourge to some degree. Endemic cretinism, the most severe consequence of iodide deficiency, has not been specifically studied and reported in Kenya as only limited attention has been paid to the public health consequences of iodide deficiency in Kenya until recently.

In 1960, the World Health Organization (WHO) published the first global review on the extent of endemic goitre [3]. This review, covering 115 countries, was instrumental in focusing attention on the scale of the public health problem of iodide deficiency disorders (IDD). It was only in the mid-1980s that the international community committed themselves to the elimination of IDD, through a number of declarations and resolutions [1,2]. WHO subsequently established a global database on iodide deficiency which now holds surveys dating back from the 1940s to date. Its objective is to assess the global magnitude of iodide deficiency, to evaluate the strategies for its control and to monitor each country's progress towards achieving the international community's goal of IDD elimination. In 1993, WHO published the first version of the WHO global database on iodide deficiency with global estimates on the prevalence of iodide deficiency based on total goitre prevalence (TGP), using data from 121 countries . Since then the international community and the authorities in most countries where iodide deficiency disorders was identified as a public health problem have taken measures to control iodide deficiency, in particular through salt iodization programmes – the WHO recommended strategy to prevent and control iodide deficiency. As a result, it is assumed that the iodide status of populations throughout the world has improved over the past two decades [3]

Iodide deficiency has been recognized in Kenya for many years now. At the beginning of the 19th century, it was suggested that the use of salt fortified with iodide would lead to good health in people living in iodide deficient areas [4]. After the pioneering work of Swiss doctors that demonstrated that iodide deficiency was indeed the cause of goitre, attempts began to locally iodize salt using a hand-and-shovel method. In Kenya iodized salt was introduced in the 1980s on a large scale in order to eliminate iodide deficiency. Due to various factors the availability of iodized salt progressed slowly. Today, over 90% of households consume iodized salt and about 70% of the salt used in industrial food production is iodized [5].

METHODS

The study was designed as a cross-sectional study to assess the factors that contribute to iodide deficiency in Coast region of Kenya. The study covered 30 clusters comprising 292 households within the region. Selection of the clusters involved multistage sampling technique; in the first stage clusters were selected using simple random sampling, and then households were selected using systematic random sampling technique. During the study, data was collected using structured interviewer administered questionnaires. The questionnaire included questions relating to the household socio-demographic characteristics, food consumption, knowledge, practices and behaviour of the respondents living in the selected household. A salt sample was collected from every sampled household for iodide level analysis using iodometric titration method as described by DeMaeyer [6].The salt was classified according to the iodide levels as; non-iodinated (5ppm), insufficiently iodinated (5 – 14ppm), adequately iodinated (15 – 45ppm) and over iodinated (>45ppm) [7]. Data were analysed using bivariate analysis and significant differences were assessed with a given significance at p<0.05

RESULTS

Socio-demographic characteristics of the participants

A total of 292 participants were enrolled in the study with the mean age of 35 ± (10 SD) years ranging between 16-72 years. Of the 292 participants, 189 (64.7%) were Christians, 71(24.3%) were Muslims, 26 (8.9%) were traditionalist and 6 (2.1%) Hindu. About 65% were married, 61% were unemployed and 14.7% were not educated (**Table 1**)

Table 1: Socio-demographic characteristics of participants

Variable	n=292	%
Age		
16 – 19	52	17.8
20 – 29	76	26.0
30 – 39	81	27.7
40 -49	56	19.2
>50	27	9.3
Marital status		
Single	58	20.0
Married	190	65.0
Divorced	23	8.0
Widowed	20	7.0
Religion		
Christian	189	64.7
Muslim	71	24.3
Traditional	26	8.9
Hindu	6	2.1
Occupation		
Employed	61	21.0
Self-employed	53	18.0
Unemployed	178	61.0
Educational level		
Primary	132	45.2
Secondary	80	27.4
College	31	10.6
University	6	2.1
None	43	14.7

Availability of iodized salt at household level

Adequately iodized salt (≥15ppm) was 26.2% of the salt samples collected in the 292 households. Two hundred and ninety two of the respondents used iodized packed salt out of which 74.8% was inadequately iodized. About 80.1% of the salt containers had cover and

82.2% of the respondents store salt in dry places. Nearly 78.4% of the participants usually add salt in the early beginning and middle of cooking while 22.6% add salt late at the end of cooking and after cooking **(Table 2)**

Table 2: Availability of adequately iodized salt at household level

Variable	n=292	%
Iodide level		
< 5	96	33
5 – 14	119	40.8
15 – 45	54	18.4
>45	23	7.8
Types of salt used		
Iodized packed salt	292	100
Coarse salt (non-packed)	0	0
Salt storage		
Dry area	240	82.2
Moist area	52	17.8
Salt container		
With cover	234	80.1
Without cover	58	19.9
Time salt added during food cooking		
Early and at the middle of cooking	229	78.4
Late at the end of cooking & after cooking	63	22.6

All the respondents demonstrated complete lack of knowledge on food sources of iodide, knowledge on iodized salt, health benefits of iodide in humans and iodide deficiency despite most of the households visited having iodized salt. The salt was mainly used to add taste to food and not considered a source of iodide.. The respondents agreed that the processed iodized salt was universally available throughout the year in the places of purchase. The respondents acquire iodized salt from various sources including supermarkets, kiosks, retail shops, and markets.

Factors associated with availability of adequately iodized salt at household level

In the bivariate analysis, having formal education (OR=3.22, 95%CI: 0.03-0.27, p=0.0436), covering of salt containers (OR=2.19, 95%CI: p= 0.0103) and storing salt in dry places (OR=0.22, 95%CI: 0.12-0.41, p=0.000001).were associated with availability of adequately iodized salt at household level. There was no association between respondents age with availability of adequately iodized salt. **(Table 3)**

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Table 3: Factors associated with availability of adequately iodized salt at household level

	Availability of iodized salt at household level				
	≥15ppm	<15ppm	OR	95% CI	p-value
Age (years)					
<19	12	40	0.86	0.37-1.98	0.7209
20-29	26	50	0.50	0.24-1.01	0.0516
30-39	22	59	0.69	0.33-1.42	0.3152
≥40	17	66	Ref		
Education level					
None	5	38	3.22	0.03-0.27	**0.0436**
Primary	31	101	1.38	0.61-3.10	0.4373
Secondary	27	73	0.83	0.36-1.93	0.6659
Tertiary	11	26	Ref		
Salt container					
With cover	54	180	2.19	1.19-4.02	**0.01032**
No cover	23	35	Ref		
Place of storage					
Dry places	49	191	0.22	0.12-0.41	**0.000001**
Moist/wet area	28	24	Ref		

DISCUSSION

Elimination of iodide deficiency is possible if more than 90% of the households consume adequately iodized salt and must be granted [8]. The study showed that 26.3% of the households had adequately iodized salt at household level. This concurs with a study carried out in Ethiopia by Hailay et al [9]. This is very low compared to a study in India where 51% of households had adequately iodized salt [10]. This can be attributed to availability and accessibility of iodized salt in the market, legislation and policies to fortify salt with iodine, regular follow ups and monitoring utilization of iodized salt. Among analyzed variable education level, place of storage and salt container was associated with iodide deficiency.

Education increases awareness and informed decision making of individuals. The study showed respondents with no education were significantly associated with consumption of inadequately iodized salt. This consistent with studies done in Pakistan [11] and Iraq [12] where household members with tertiary education used iodized then those illiterate. Fortification of salt with iodine is not enough to alleviate iodide deficiency hence education should play a role in communicating information about importance of consuming adequately iodized salt to the population.

Iodine stability is critical for the success of salt fortification. High humidity results in rapid loss of iodine from iodized salt ranging from 30-98% of the original iodine content. Storage of iodized salt in dry places and covering the salt containers was associated with availability of adequately iodized salt. This is in agreement with a study done in India where consumption of iodized salt was high in those storing salt in closed containers than those in the open containers [13].

Limitation: This study however did not interrogate the period of storage of the salt between purchase and consumption which is an important factor in salt iodide losses. Iodine level determination did not include titration level of iodine in salt and urinary iodine for body iodine level determination.

CONCLUSION

Availability of adequate iodized salt at household level was very low when compared to the WHO recommended levels to prevent iodide deficiency. Formal education, covering salt containers and storing salt in dry places were associated with availability of adequately iodized salts at households. Therefore there is need to sensitize people on importance of adequately iodized salt and how to handle it.

Conflict of interests

The authors declare no conflict of interests

Authors' contributions

KK: Primary author was responsible for formulation of the research concept, designing the study, collection of data and analysis, interpretation of results and writing up the draft manuscript. CM: Conception, design and coordination of the project, data analysis and interpretation and writing and review of the draft manuscript. AM: Conception, design and coordination of the project, data interpretation and writing and review of the draft manuscript

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