DEVELOPMENT OF A VITAMIN A-FORTIFIED MANGO NECTAR FOR PRIMARY SCHOOL CHILDREN IN KENYA

BY

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DECLARATION

I, Anne M. Wangalachi, hereby declare that this dissertation is my original work and has not been presented for a degree in any other university

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DEDICATION

I dedicate this work to my parents, David and Susan Wangalachi – my first teachers – who nurtured my love of books, indulged my curiosity and encouraged me to always strive for the best.

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OPERATIONAL DEFINITIONS

Estimated Average Requirement	A nutrient intake value that is estimated to meet the requirements of half of the healthy individuals in a group. This value is used to assess the adequacy of intakes of population groups and, along with knowledge of the distribution of requirements, to develop RDAs.
Juice (100%)	100% juice is pure juice; is not produced from concentrate and has not been adjusted
Juice drink/beverage	A drink/beverage which is low in juice, containing between 10% and 20% juice
Nectar	Mango nectar is produced by mixing the mango puree or pulp with citric acid, sugar and water; with pulp content varying between 25% and 50%.
Organoleptic	Any sensory properties of a product, involving taste, colour, odour and feel. Organoleptic testing involves inspection through visual examination, feeling, tasting and smelling of products

Overage — The additional amount of fortificant added to the food to compensate for losses, which will ensure that the fortified food delivers the targeted level of nutrients at the time the food is used at home or point of consumption.

Pulp purée — This is the direct or first extract from fruit, entirely made of fruit and contains no water or any other ingredient. it is usually more viscous than juices.

Recommended Daily Allowance (RDA)

The average daily dietary intake sufficient to meet the nutrient requirements of nearly all (97% to 98%) healthy individuals in a group.

Supplement — Food material that is conveniently added to another food (during preparation or serving) in small quantities to boost its nutrient content

Tolerable Upper Intake Level

The highest level of daily nutrient intake that is likely to pose no risks of adverse health effects to almost all individuals in the general population. Risk for adverse effects increases as intake increases above the upper intake level.

Vehicle	A vehicle is the food that is to be fortified
VAD disorders	Physiologic disturbances secondary to VAD. VAD disorders are defined as any health and physiologic consequences attributable to VAD, whether clinically evident (e.g. xerophthalmia, anaemia, growth retardation, increased infectious morbidity and mortality) or not (e.g. impaired iron mobilization, disturbed cellular differentiation and depressed immune response).
VAD	State of inadequate vitamin A nutriture. VAD is defined as liver stores of below 20 µg/g (0.70 µmol/ g) of retinol. Serum retinol levels may still be within the homeostatically regulated normal range. By convention, serum retinol levels <20 µg/dL (0.70 µmol/L) are considered deficient

ABRREVIATIONS AND ACRONYMS

AOAC	Association of Official Analytical Chemists
ASLT	Accelerated Shelf-life Testing
BHA	Butylated Hydroxyanisol
BHT	Butylated Hydroxytoluene
FAO	Food and Agriculture Organization of the United Nations
FPE	Free Primary Education
GOK	Government of Kenya
HPLC	High Performance Liquid Chromatography
ILSI	International Life Sciences Institute
IOM	Institute of Medicine
KHDP	Kenya Horticultural Development Programme
KOH	Potassium Hydroxide
KSh	Kenya Shillings
MDGs	Millennium Development Goals
MI	Micronutrient Initiative
MOST	Micronutrient Project of the United States Agency for International Development
OFSP	Orange-fleshed sweet potato
PET	Polyethylene terephthalate
PPM	Parts per million
NIDs	National Immunization Days
RDA	Recommended dietary allowance

RE	Retinol equivalence
US	United States
USAID	United States Agency for International Development
VAD	Vitamin A deficiency
VMD	Vitamin and mineral deficiencies
WHO	World Health Organization
UNICEF	United Nations Children's Fund

ABSTRACT

Vitamin A deficiency (VAD) is a serious public health problem in Kenya: threatening the achievement of the Millennium Development Goals (MDGs) by 2015, and its Vision 2030, by 2030 particularly on poverty reduction and universal primary education. Currently the main VAD alleviation strategies in use in Kenya do not adequately reach this 'forgotten' age group: 6 to 18 years. There was a need therefore for developing a low-cost intervention product that could fill this gap.

The main objective of this study was to develop an acceptable, affordable, safe and stable vitamin A-fortified mango nectar, for use as a vitamin A-rich food supplement for primary school children. A sub-objective was to determine the potential of the developed mango nectar in alleviating VAD and fitting into existing school feeding programs.

In this study, the product - a vitamin A fortified mango nectar - was optimized for formulation, sensory properties, nutrient stability, safety and storage stability. The final product was subjected to consumer acceptability studies by pupils of Loresho Primary School, who were identified to participate in the study.

The best formulation was found to be 50% pulp, 39.3% water, 0.5% citric acid, 10% sugar and 0.2% potassium metabisulphite. The sample stored at 4°C was found to be the most stable and to remain the most acceptable, to maintain the best levels of sensory and biochemical attributes, and to supply at least 100 RE (333 IU) vitamin A. The changes in

the quality attributes of the product were significant in the samples stored at both 25°C and 38°C.

Majority (98.5%) of the pupils confirmed that they liked the product and would ask their parents to buy it. The product has a great potential of fitting into a school feeding programme and of alleviating VAD. At the 20% RDA level of fortification the cost of the product is comparable to what most beverages available to the school children cost (although they are not fortified). The cost of fortification is minimal or negligible coming to less than 1 Kenyan cent (KSh 0.01) per child. The final product cost was KSh 21.20 per 250-ml bottle.

It was feasible to produce an affordable, acceptable, safe, and stable fortified mango nectar for use as a food supplement among primary school children. Both the project and product represent opportunities for new business. It is recommended that the production of the fortified product be scaled up to increase supply. It will also be necessary to conduct a bioefficacy study among the target school pupils.

CHAPTER ONE INTRODUCTION

1.1 Background information

Vitamin and mineral deficiencies (VMDs) are a significant cause of malnutrition and associated ill health among populations in Kenya, and other developing nations. The most prevalent and important deficiencies are those of iron, iodine, zinc, vitamin A and folate. These deficiencies lead to a variety of health complications with women and children being worst affected

Globally, the statistics are shocking: vitamin A deficiency (VAD) is responsible for 9% of child deaths and 13% of maternal deaths. Nearly 50% of all anaemia is caused by iron deficiency and anemia in pregnancy contributes to 18% of maternal deaths. When mothers are iodine-deficient, the intellectual health of their babies is interfered with. About 6% of all child deaths is caused by zinc deficiency. On its part, folic acid (folate) deficiency results in more than 240,000 neural tube defects. It is also quite common to find a person suffering from more than one VMD. Most of these conditions and deaths are easily preventable but continue to rob countries of at least 1% of their gross domestic product (GDP) as they persist. Vitamin A deficiency (VAD) is known to be prevalent in Kenya. VAD causes problems that range from mild and often reversible to severe (and often irreversible).

A variety of solutions to combat VMDs exist and include supplementation, breast feeding, food fortification and dietary diversification with increased intake of animal foods, fresh fruits and vegetables. However, VMDs persist because some of the VMD alleviation interventions may not be accessible to the most vulnerable due to inadequacies of supplementation and food fortification programmes, or due to poverty. Poverty means that people often cannot afford to buy and eat micronutrient-rich food (variety of fruits and vegetable, and meat products) and that they can only afford to live in unsuitable housing with poor sanitation services and lack access to safe drinking water. These conditions only worsen their VMDs and also expose them to such others as diarrhoea and malaria, which have been shown to worsen micronutrient health status; this is a vicious vortex. Currently, in Kenya, there is a shortage of clean, potable drinking water and also there has been a proliferation of fruit drinks and juices in the market which are prepared from water of questionable quality, and which especially target young children – further exposing them to diarrhoea.

Food based approaches – dietary diversification and fortification – have been established to be effective in ending or reducing VMDs in developed countries. In Kenya, too, these food based approaches have been used with considerable success and include promotion of production and consumption of orange-fleshed sweet potato, fresh fruits and vegetable (through home and school gardens) and fortified foods including oils, salt and maize flour[1].

Among the dark green leafy vegetables being promoted are amaranth, spinach, and black nightshade. The fruits include mango, papaya and watermelon. Though good, this approach is affected by the seasonality and availability of the fruits and vegetables. Also the bioavailability of vitamin A from the dark green leafy vegetables is lower than that from fruits, which are also more palatable. Therefore fruits like mango present a tastier

[1] This is based on interaction with people in the industry

and more effective source of pro-vitamin A. Mangoes, if consumed fresh, have enough beta-carotene (provitamin A) to adequately meet the recommended daily allowance (RDA) for vitamin A; supplying between 307 and 400µg Retinol Equivalents (MacLaren and Frigg, 2001a; Sehmi, 1993). However, the main challenge to the utilization of mangoes as an ideal source of provitamin A is seasonality and high perishability.

Although Kenya produces a substantial amount of mangoes, postharvest losses have in the past contributed to huge wastes. One of the initiatives designed to reduce these losses and to increase mango production, has been implemented by the United States Agency for International Development (USAID), through the Kenya Horticultural Development Programme (KHDP). The project has been working in collaboration with mango growers and processors at the Kenyan Coast to improve the quality of mango availed for processing, through better post-harvest management, thereby increasing utilization and optimizing the returns to the growers (New *et al.*, 2005)

However, these efforts are not enough; extracting the pulp from mango and preserving it by processing will reduce post harvest wastes and also ensure that a mango raw material is available even when the mango fruit is out of season. This will ensure continued supply of the raw material and mango-derived drinks; also ensuring consistency in the quality and taste of the pulp and derived drinks throughout.

Most Kenyans already consume freshly prepared mango drinks, usually comprising mango fruit pulp mixed with water, and sometimes sweetened with sugar. The potability and safety of the water cannot always be guaranteed since its source and quality may not always be known. Processing the fresh mangoes or pulp into nectars or juices can contribute to increasing availability of safe beverages for consumption by the Kenyan population, while enhancing the utilization of the available mangoes.

However, the concentration of provitamin A in the final processed mango drink is often lower than that in the fresh mango as a consequence of processing, necessitating the fortification of this product in order to supply the RDA of vitamin A to the consumers. Fortification with vitamin A provides a means of compensating for the loss of nutrients during processing, adds more of the nutrient to the product and gives the RDA of vitamin A in a form already familiar to the consumers – it therefore does not necessitate a dietary behavior change.

1.2 Problem statement

There is an important age group – primary school children which is often neglected or ignored, when programmes to alleviate VMDs are designed. There are programmes targeting infants and young children (VA supplementation) and those targeting women (iron and folic acid supplementation).

So far food-based approaches offer the best opportunities for reaching this age group with vitamin A. There are many options locally available which make use of local resources, however each has its individual limitations. Currently, the vitamin-A fortified foods sold in Kenya are cooking oil and margarine. Animal products are often considered very expensive and fortified foods few. Weaknesses in the current diet-based solutions are that fresh fruits like mango, though a good source of dietary pro-vitamin A, are seasonal and highly perishable while dark green leafy vegetables are not very palatable.

When in season, mangoes are consumed either as fresh sliced fruit or processed into juice by majority of Kenyans. During these periods the fruit is sold quite cheaply since there is usually oversupply; more mango is available than can be fully absorbed by the market. Often, this mango goes to waste and in areas where farmers cannot reach markets, it is usually fed to livestock or left to make manure on the farm.

Encouraging consumption of fresh fruit and mango juice by the target populations when the fruit is in season will go a long way in alleviating the VAD problem among them. However, extending the availability of the mangoes through preparation and preservation of mango pulp can even out the consumption of mangoes all year-round. It would involve obtaining all the mangoes while in season and preserving them.

Although fats and oils have been fortified with vitamin A, they are not easily accessible by the target group, except when consuming food prepared with these fortified fats and oils. Also, so far data is not available on how much has to be consumed to meet the RDA or a proportion of it. There is thus a need to get a food vehicle that is more suitable and fits in well with the target group's dietary habits: one that is portable, convenient and can be consumed anywhere, especially at school.

1.3 Justification

Food based approaches - dietary diversification and fortification - have been found to be effective in ending or reducing VMDs in developed countries, and hold potential in developing countries too (ILSI and FAO, 1997). However, the success of dietary diversification may be impeded by poverty which may take the requisite foods out of the reach of the poor, and ill health which results in malabsorption of the micronutrients. Food fortification, on the other hand, holds great promise in reaching considerable proportions of the vulnerable populations, both in urban and rural areas, through the right food vehicles (Singhvi *et al*, 2007).

Fresh mangoes have great potential as part of a food-based VAD alleviation strategy as they contain enough beta-carotene (provitamin A) to adequately meet the recommended daily allowance (RDA), by supplying between 307 and 400μg Retinol Equivalents. However, mango production and availability is seasonal in nature (Griesbach, 2003). Moreover, the pro-vitamin A they contain needs to be converted into retinol once inside the human body – it is not supplied directly (ILSI and FAO, 1997).

Kenya has a high production of mango, mainly in Eastern and Coast provinces, with this production being seasonal in nature: characterized by periods of glut and scarcity (New *et al*, 2005). However, this mango does not have much exploited commercial value in Kenya: there is a lack of avenues for exploitation of surplus mango and most of it goes to waste. Preserving the freshly harvested mango into pulp presents a viable means to ensuring the supply of mango-derived drinks even during the off season, thus ensuring the consistency of quality, taste, availability and price of the derived drinks (New *et al*, 2005).

In the 2003 Kenya Health and Demographic Survey (CBS, 2003), the promotion of food-based strategies, especially innovative public-private partnerships in food fortification and/ or enrichment, were recommended as being key in alleviating VMDs, of which VAD is one. At the national level, food fortification has the capacity to reach considerable proportions of the vulnerable populations, both in urban and rural areas Food fortification offers an opportunity of solving common problems using common resources

However, although processed pulp will increase the availability of mango-derived drinks, its contribution to effectively alleviating VAD is limited since as in every processing operation, there is loss of nutrients and the mango pulp contains less provitamin A than the fresh fruit or fresh juice. Fortification with vitamin A presents a means of increasing the amount of nutrient available in the final product.

Therefore developing a mango nectar and fortifying it with vitamin A presents a key component in food-based approaches to combating VAD and this project represents a food technology contribution to the alleviation of VAD through the preservation of the mangoes to increase their availability between seasons and anywhere it is needed.

Mango nectar as a vehicle is ideal for increasing direct access to the vitamin A (as retinol) by the target group. The fortified mango nectar is also very acceptable and the vitamin A it provides is comparable to that from animal sources.

The role of this research project was to give an appreciation of how much consumption of the fortified mango nectar will contribute to the well being of primary school children who are the most vulnerable to VAD and the product provides a good solution to maintaining their good health. Both the product and project contribute to promoting equal opportunities in nutrition for all children, in line with the Kenya government's 'education for all' policy. With improved health, the primary school children will have less illness-induced absenteeism, better cognitive ability and thus take full advantage of the opportunities offered by Kenya government's free primary education. This can be implemented in a way similar to the Kenya government's primary school milk programme that ran from the 1970s to the early 1990s. This programme supplied free milk to all the primary school pupils in all corners in the country.

Furthermore, processing this mango into mango nectar and fortifying it with vitamin A would present another option for meeting this target group's vitamin A RDA needs. The project and approach are suitable because the product does not present or require any changes in dietary habits, it would be readily available, hygienically produced, stable and acceptable. It also solves the problem of lack of safe soft drinks for consumption by the target group – primary school children – especially those in low income areas.

The project will also provide new business opportunities for mango farmers, the pulp and fortified mango nectar processors, suppliers of the food fortificant and distributors of the fortified product. The product as an intervention is both sustainable and feasible: it can be consumed daily; it is a thirst quencher, and supplies at least 20% vitamin A RDA to the target population. Its subsequent uptake by the local food processing industry will increase the accessibility and availability of the product by the at-risk populations.

1.4 Aim of the study

The aim of the study was to contribute to nation-wide efforts to alleviate VAD and to achieve the Millennium Development Goals (MDGS) of facilitating attainment of universal free primary education, reduction of child mortality and improvement of maternal health.

1.5 Purpose of the study

The purpose of the study was to establish the feasibility of producing a low cost, stable and acceptable vitamin A-fortified mango product, for use as a food supplement for primary school children, in alleviating VAD.

1.6 Project objectives

1.6.1 Major objective

The major objective of this study was to develop a stable and acceptable vitamin A-fortified mango nectar for use by primary school children in Kenya.

1.6.2 Specific objectives

1. To identify sources of vitamin A available to the primary school children in the identified study area
2. To develop a mango nectar and fortify it with vitamin A

3. To determine the sensory properties the fortified mango nectar

4. To determine the storage stability of the developed mango nectar fortified with vitamin A

5. To determine consumer acceptability of the developed vitamin A fortified mango nectar among the target group

1.7 Research Questions

1. Can the mango nectar be fortified with vitamin A?

2. What is the storage stability of a mango nectar fortified with vitamin A?

3. What is the sensory property of a mango nectar fortified with vitamin A?

4. What is the consumer acceptability level of a fortified mango nectar?

CHAPTER TWO LITERATURE REVIEW

2.1 Vitamin A and its contribution to good health

2.1.1 Chemical nature and occurrence of vitamin A

Vitamin A is a family of fat-soluble vitamins together with vitamin D, E and K. Retinol is one of the most active or usable forms of vitamin A and it is found in animal based foods such as the liver and eggs. Retinol is often called pre formed vitamin A and it can be converted to retinal and retinoic acid (McLaren and Frigg, 2001b). The acid form, retinoic acid, in almost all tissues, carries out the vitamin A functions. Recently, other functional acid derivatives have emerged such as 9-cis retinoic acid and all-trans-oxo-retinol (McLaren and Frigg, 2001a). Some plant foods contain dark coloured pigments called provitamin A carotenoids that the body can convert to vitamin A. Approximately 70-90% of vitamin A consumed by majority of people in the developing world is provided by these provitamin A carotenoids (McLaren and Frigg, 2001a).

2.1.2 Vitamin A utilization

Digestion and absorption

Dietary preformed vitamin A and carotenoids are released from protein in the stomach by proteolysis (McLaren and Frigg, 2001a; McLaren and Frigg, 2001b). They then aggregate with lipids and pass into the upper part of the small intestines. Vitamin A enters the body in two forms: as preformed vitamin A from animal sources and as precursor carotene from plant sources. The conversion of β-carotene into vitamin A takes place in the walls of the intestines and even the most efficient intestines can absorb and convert only a portion of the β-carotene in the diet; thus 12mg of β-carotene in food is converted to equivalent of about 1mg of retinol (McLaren and Frigg, 2001a, McLaren and Frigg, 2001b).

Transport, storage and metabolism

In the liver, both preformed vitamin A and provitamin A carotenoids are stored as the retinyl ester in the stellate cells. Retinol is subsequently attached to the retinol binding protein (RBP), and transthyretin, in order to be transported to other parts of the body Once retinol is delivered to the cell, it is picked up at the cell membrane by RBP receptors. Cellular retinol binding protein (CRBP) is found within the cell and it directs retinoids to particular enzymes and the cell nucleus (McLaren and Frigg, 2001a).

2.1.3 Physiological functions of vitamin A

Vitamin A contributes to physiological functions that include vision, cell differentiation, growth, reproduction and boosting of immunity. Deficiency symptoms include night blindness, changes in the eye, deficiency effects on the epithelium and increased susceptibility to infectious diseases (McLaren and Frigg, 2001b).

2.2 Vitamin A deficiency in Kenya

Vitamin A deficiency (VAD) occurs when an individual's serum retinol levels fall to below 0.70 µmol/litre serum retinol; with a public health problem existing when over 20% of the population has serum retinol levels below this cut-off point (CBS, 2003). In Kenya, Vitamin A deficiency (VAD) is known to be prevalent, particularly in mothers and children found in the Eastern and Coastal parts of the country. Moderate and severe VAD in children exists, and in 2003 stood at 14.7% and 61.2%, respectively. In mothers the acute and moderate levels of VAD were found to be at 9.1% and 29.6%, respectively (CBS, 2003).

2.3 Vitamin A deficiency prevention and control strategies

VAD prevention and control interventions fall into three main groups: supplementation, dietary modification and fortification. The current practice is to have an integrated approach, with more than one of these interventions being implemented concurrently.

Supplementation usually involves prophylactically administering large doses of vitamin A in liquid or capsule form, at 4 - 6 month intervals, to treat patients with VAD and to protect pre-school children and lactating mothers from VAD (MacLaren and Frigg, 2001a). Supplementation is easy to initiate, though coverage levels fall, unless it is incorporated into other long term programmes such as the national immunization days (NIDs) when children are usually vaccinated against polio. As polio becomes gradually eliminated though, some countries have begun child health days, to ensure that children still receive the scheduled vitamin A supplements, at least once a year. For example, in Uganda, in 2004, May and November were designated as the months for the biannual Child Days, whereby children between 6 months and 5 years, received vitamin A capsules among other health interventions. In May 2004, coverage was estimated at 76%. Although there may have been concerns about potential vitamin A toxicity from the large vitamin A doses, studies have shown that supplementation with vitamin A of at most 10, 000 IU daily is extremely safe, for pregnant women and children aged between 1-6 years (McLaren and Frigg, 2001a; Sanghvi *et al*, 2007). The cost of supplementation has been pegged at a few US dollar cents per capsule, thus making it a low-cost, extremely effective means of improving the vitamin A status of various population groups that can be scaled up to the national level (Sanghvi *et al*, 2007).

Dietary modification or diversification entails identification and increased incorporation of locally available sources of vitamin A into diets by a community or individual. Plant foods with good provitamin A activity include orange/yellow fruits, tubers as well as dark green leafy vegetables. Tree fruits such as mango and papaya, though lower in provitamin A activity than dark green leafy vegetables, have greater vitamin A bioavailability and acceptability among consumers than the latter (MacLaren and Frigg, 2001a; Rodriguez-Amaya, 1997; Olson, 1996). These are important vitamin A sources, especially in developing countries, like Kenya, where majority of the population cannot afford animal sources of pre-formed vitamin A. Biotechnological advances have led to development of "golden rice" and orange-fleshed sweet potatoes (OFSP), modified to contain β-carotene. HarvestPlus, through the International Maize and Wheat Improvement Centre (CIMMYT) is developing maize with enhanced provitamin A concentrations and improved nutritional value as a contribution to global VAD alleviation efforts (Ortiz-Monasterio *et al.*, 2007). Trials on acceptability of the OFSP have been conducted in some countries, including Kenya and Uganda (Sserunjogi and Harvey, 2005). In Uganda, the OFSP was found to be more acceptable among children than adults, partly due to its attractive colour (Sserunjogi and Harvey, 2005). Communities are encouraged to establish home or school gardens to improve availability of plant foods rich in provitamin A and to provide additional income, that can be used to purchase meat and eggs, rich in pre-formed vitamin A.

Food fortification – the addition of micronutrients to food to increase their amounts in that food – has been used to control vitamin A deficiency in industrialized countries. Vitamin A added to fortified food supplies about 20-50% of the vitamin A consumed in Europe (UNICEF, 1997). Fortification has been viewed as being central to VAD prevention and control, when integrated with other interventions. There are various factors to be considered for successful vitamin A (and other micronutrient) fortification of food. Availability of a suitable vehicle is paramount, as is both public and private sector support. The ideal fortification vehicle should be one that: can be afforded and is consistently consumed by a considerable proportion of the at-risk population – including the poor; whose taste, smell and appearance are negligibly affected by fortification; does not negatively react with the fortificants; maintains the stability of the micronutrients over the shelf-life of the product and throughout the cooking process (ILSI/FAO, 1997; MI and UNICEF, 2004; Mutuku *et al.*, 2005). Usually, a micronutrient is added at levels representing a third of the individual's RDA. So far, vitamin A vehicles have included: wheat- and maize flour; sugar, edible oils, margarine, dairy products and specialty foods (MacLaren and Frigg, 2001b; UNICEF, 1997). The case is made for fortifying several vehicles, as this provides complementary coverage, wherever there may be irregular consumption. Vitamin A is unstable under conditions of low pH, heat, high humidity, light and oxygen – presenting a challenge during both processing and storage of the various food vehicles (Rodriguez-Amaya, 1997).

2.3.1 Sugar fortification with vitamin A

Sugar makes an appropriate fortification vehicle for vitamin A, as it is consumed in fairly regular amounts by a majority of the world's people (Sight and Life, 2006a). Retinyl palmitate is added to a small amount of sugar to form a premix. This is in order to produce a homogenously fortified product. The premix also contains an unsaturated fat vegetable oil, to adhere the vitamin A beadlet to the sugar crystal to prevent separation of the vitamin A crystal from the sugar. This thus preserves the sugar's original organoleptic properties (Sight and Life, 2006a). It is also necessary to add an antioxidant such as ascorbyl palmitate, alpha-tocopherol and lecithin, to prevent oxidation of the oil, which would destabilize the vitamin A and result in undesirable sensory characteristics of the sugar (Sight and Life, 2006a). 250-CWS, the commercial form of retinyl palmitate, is added to the sugar before it passes through the drying turbines, as it is stable at 105 °C for only 10 minutes (Sight and Life, 2006a). Any losses of retinol during processing and storage are compensated for by adding the suitable overage of premix (Sight and Life, 2006a). Guatemala was one of the first nations to successfully implement a sugar fortification programme, greatly reducing vitamin A deficiency among children with severe VAD. Currently, fortified sugar accounts for 50% of all vitamin A in the Guatemalan diet (Sight and Life, 2006a, Mutuku *et al.*, 2005)

2.3.2 Maize flour fortification with vitamin A

Maize flour is considered for fortification since it is widely consumed all over the world and accounts for a significant proportion of intake, ranging from 10% to close to 70%, depending on the region. In Central America, this value is 50%, while in Zambia and other parts of Africa, it accounts for two-thirds of all energy intake (Sight and Life, 2006b). Maize flour is fortified with several vitamins and minerals that include vitamin A, iron, thiamin, riboflavin, niacin, folate and pyridoxine (Sight and Life, 2006b). In most fortification programmes, flour is processed centrally, for more effective quality control. In Zambia and Zimbabwe, however, evaluation of hammer-mill fortification was done and found to be effective. Vitamin A stability in fortified maize flour stored at room temperature and low humidity is good with 95% retention after six months (Sight and Life, 2006b). At 45°C, fortified maize flour retained 67% vitamin A, after 12 months of storage (Sight and Life, 2006b). In Venezuela, precooked maize flour is fortified with vitamin A, contributing to more than 80% of the RDA (Sight and Life, 2006b). In Zimbabwe and Namibia, government support was provided for commercial maize meal fortification with vitamin A (at 25% RDA after cooking) (Sight and Life, 2006b). In Kenya, maize flour has been industrially fortified with iron and vitamin A (Mutuku *et al.*, 2005).

2.3.3 Oils and margarine fortification with vitamin A

Edible oils are a rich source of energy, fat-soluble vitamins (A, D, E) and essential fatty acids and are consumed by most people. Vegetable oils form appropriate vitamin A vehicles due to the centralized nature of oil production and refining. Additionally, vitamin A is most stable in oils and the oil enhances the body's absorption of vitamin A. During oil fortification with both vitamin A and D, antioxidants, both natural and edible, such as butylated hydoxytoluene/ butylated hydoxyanisol (BHT/BHA) and α-tocopherol, are added to stabilize the vitamin A and oil. Oxidized oils cause faster oxidation and degradation of vitamin A (Sight and Life, 2006c). β-carotene is also added to margarine to enhance the colour and the vitamin A content (Sight and Life, 2006c). Vitamin A added to margarine maintains its stability throughout processing and home storage. Heating fortified margarine to temperatures of between 160°C and 180°C, however, results in vitamin A losses ranging from 20 to 50 percent, respectively. Vitamin A losses during frying are directly proportional to the number of times the oil is used for frying food (Lavaro *et al.*, 1991).

2.3.4 Fortification of beverages with vitamin A

Consumption of fruit juices or fruit-based soft drinks is fast gaining ground, worldwide, as consumers become increasingly aware of the health benefits to be derived from the same. Fortifying fruit based beverages with various vitamins and minerals presents an opportunity for adding value and functionality to the beverages, since consumers are able then to get more health benefits from the drinks, while food companies can acquire a marketing advantage. Fortified fruit juices are currently in the mainstream in the United States (US) and with some manufacturers specifically targeting children and their parents. Their popularity is also contributed to by the fact that a dietary behavioral change is not really required (Hazen, 2007).

Industrially, fruit juices have been fortified with vitamins A, C, E, D, B3, B6, calcium and iron. In the US, certain beverage manufacturers have been successful in catering to different market segments' needs. For children, kiwi and strawberry juice have been fortified with vitamins A, C, D, B3, B6, calcium and iron (Hazen, 2007). More and more processors are using fruit juice concentrates as the bases for the added micronutrients since they greatly improve the flavor and color profile of the developed beverages, naturally. Additionally, fruit concentrates blend well and people already link good health to them. The most popular bases are mango and guava (Hazen, 2007). Additionally, carrot juice concentrate is being blended with fruit juices due to its significant β-carotene content to impart an attractive orange color and to improve the vitamin A content of the beverages (Frank, 2000). In Europe, juices and fruit juice based soft drinks have been mainly fortified with β-carotene, due not only to its remarkable stability during processing and storage, but also due to its attractive colour (DSM personal communication, 2006) .

Fernandez *et al.* (2006) developed two prototype variants of β-carotene-rich juice by combining carrot juice with mango and pineapple. The carrot-mango juice contained 720μg β-carotene/100g, while that of the carrot-pineapple juice was 566μg β-carotene/100g. The juices developed scored highly during sensory evaluation, with a general acceptability score of 6.5, for carrot-mango juice and 6.7 for carrot-pineapple juice (corresponding to "like very much") on a seven-point Hedonic Scale. At room temperature, and packaged in 375 ml glass bottles, the juices were quite shelf-stable: 12 months for the carrot-pineapple juice and 10 months for the carrot-mango juice. The retention of β carotene/ vitamin A in the carrot-mango juice and carrot-pineapple juice was 67.2% and 86.6%, respectively. These researchers concluded that 500 ml of reconstituted carrot-pineapple juice and 375 ml of reconstituted carrot-mango juice would provide 35% and 33%, respectively, of the vitamin A RDA of 4-6 children (Fernandez *et al.*, 2006).

In 1996, Ash *et al.* conducted a six-month study on the effect of an orange flavoured fortified drink on the health and nutrition of Tanzanian school children. The drink was prepared by mixing two tablespoons of the orange-flavoured powder fortified with 11 micronutrients that included: iron, zinc, iodine, vitamins A and C, folate, niacin, thiamin, riboflavin and pyridoxine. The study children were divided into two equal groups. One half drank the fortified juice, while the other half received a similar unfortified drink. All children with intestinal worms were treated with an anti-parasite drug at the onset of the study. It was found that the drink supplies 30 percent to 120 percent of the U.S. RDAs for the micronutrients it contained. Additionally, the fortified drink not only significantly improved nutritional deficiencies but also brought almost twice as much weight gain and 25 percent greater gain of height in children who consumed the drink compared to the children who drank a placebo. Among the consumers of the fortified drink, most of the children with moderately severe anaemia showed significant improvement in iron levels while many of the consumers of the non-fortified drink showed a decline in levels (Ash *et al.*, 2003). The authors thus concluded that physiological doses of micronutrients were quite effective in preventing and controlling micronutrient deficiencies as compared to megadoses as supplied during supplementation.

The key issues to be considered in fruit juice fortification with vitamin A are the stability of the vitamin A form to be used, the colour, flavour and overall acceptability of the developed product. Vitamin A stability in foods during processing and storage is affected to varying degrees by factors that include: low pH, light, oxygen, heat, and high moisture/high relative humidity. These conditions promote the degradation of vitamin A through isomerization and oxidation. These considerations thus affect the choice of packaging material and storage and processing conditions to be employed. Oxidation of the vitamin A would in turn lead to not only the development of an undesirable colour and flavour of the product in which it is contained but also to decreased availability of the vitamin A in that food (Rodriguez-Amaya, 1997). Nutritional Products Ltd, whose products include micronutrient premixes for use in industrial fortification, conducted studies on vitamin A stability in beverages in 2001 and 2002 in Europe. An orange drink containing ten percent fruit juice was fortified with five commercial forms of vitamin A and packaged in different materials and conditions and stored at room temperature (18 23°C). The vitamin A forms used were: dry vitamin A acetate, type 325 CWS/F; dry vitamin A acetate, type 250 CWS/A; dry vitamin A palmitate, type 250 S/N; dry vitamin A palmitate, type 250 CWS and dry vitamin A palmitate, type 250 CWS/F. The packaging conditions were: clear glass without CO_2, PET with CO_2, clear glass with CO_2, light protected glass without CO_2, PET without CO_2 and light protected glass with CO_2 It was concluded that vitamin A palmitate was more stable compared to vitamin A acetate; however the acetate form lent itself better to use in manufacture of fortified fruit drinks. (DSM personal communication, 2006).

2.4 Sensory evaluation and shelf-life determination of food products

Sensory evaluation of foods refers to the examination of its various attributes by the human senses of sight, smell, taste and sometimes touch/feel, to determine its overall acceptability. Organoleptic refers to any sensory properties of a product, involving taste, colour, odour and feel. Organoleptic testing involves inspection through visual examination, feeling and smelling of products. Thus sensory evaluation and organoleptic testing can be used interchangeably and have gained significance in new food product development, due to their usefulness in determining product acceptability as well as shelf-stability (Labuza, 2000).

2.4.1 Sensory evaluation

Sensory evaluation is usually carried out using either trained panelists or carefully selected consumers. In sensory evaluation, it is important to carefully prepare and serve the food samples, mimicking the usual consumption conditions – environment, time, serving temperature and quantity – as much as possible to obtain best results. Additionally, the samples should be as uniform as possible to remove any variability in sample and subsequent panelists' test scoring of the same. There is also blinding, whereby the product samples are assigned three-digit random numbers. It is important to clearly define the experimental variables, sampling frequency as well as sample presentation sequence (Labuza, 2000). Having a reference sample that will "fix" the food's properties and intensities that will be measured during the sensory evaluation session is necessary. The reference sample is also useful in checking the ability and consistency of the panelists.

In order to prevent panelist fatigue, it is important to have a 15- to 30-minute interval between samples, with the longer interval for foods with lingering after flavours or persistent residual mouth sensations. Panelist fatigue also will affect the total numbers of samples evaluated as well as order of sample presentation. For descriptive sensory evaluation of beverages, only small portions are required. It is, however, necessary to ensure that there is more than enough sample available to facilitate optimal sensory exploration and detailed evaluation of the product attributes (Labuza, 2000). The beverage samples may be presented in Pyrex beakers and marked with a random 3-digit code. Aroma, appearance, flavour, texture and tactile modes are used to evaluate food by descriptive sensory panels, with an intensity scale being used to rate each of the products.

The Hedonic Scale is commonly used; with 1 corresponding to "dislike very much" and the highest value corresponding to "like very much." In a seven-point Hedonic Scale, a score of 7 would correspond to "like very much".

2.4.2 Shelf-life testing

Shelf-stability may be defined as the ability of the product to remain acceptable in terms of quality and safety under given storage conditions. Conversely, shelf-life is the time until a product ceases to be safe and acceptable to the consumer, under given storage conditions. Formulation, processing, packaging and storage conditions affect the microbiological, enzymatic and physicochemical reactions that take place concurrently in any given food. Important aspects of the storage microenvironment of the processed food include gas composition (O_2, CO_2, inert gases, ethylene), relative humidity, pressure, light and temperature (Labuza, 2000).

There are various approaches for determining shelf-life and they include approximation by use of published data, comparison with known distribution times for similar products on the market or using consumer complaints to determine occurrence of problems. In using the distribution test method, product is collected from market sites and stored in the laboratory under conditions similar to those it would be at home (Labuza, 2000). Commonly, accelerated shelf-life testing (ASLT) is being used, whereby the finished product/package combination is under abuse conditions such as extremes of temperature, relative humidity or pressure. This is followed by periodic examination of the food product until the end of shelf life and extrapolating this data to true distribution conditions, thus estimating the true shelf life of the product (Labuza, 2000). ASLT provides a quick and effective means of determining shelf-life of developed food products. Indices used in shelf-life determination include sensory evaluation, in addition to chemical, microbiological and physical testing through both classical and instrumental means.

2.5 Ngowe variety of mango

The original Ngowe tree (so it is believed) was brought from Zanzibar and planted in Lamu approximately 106 years ago. This typical coastal cultivar, also known as Lamu mango, can now be found all along the coastline and has also adapted well to medium altitude locations (Griesbach, 2003).

Ngowe is the most easily recognized of the local mango fruits. It is large, oblong and slender with a very prominent hook-like beak at the apex. From pale green, the fruit develops to a most attractive yellow to orange colour when ripe. The deep yellow flesh is of excellent quality, virtually free from fibre, melting, and carries no turpentine taste. The average fruit length measures 14 cm with a width of 9.5 cm, and a weight range of 425–600 g (mean: 523 g).

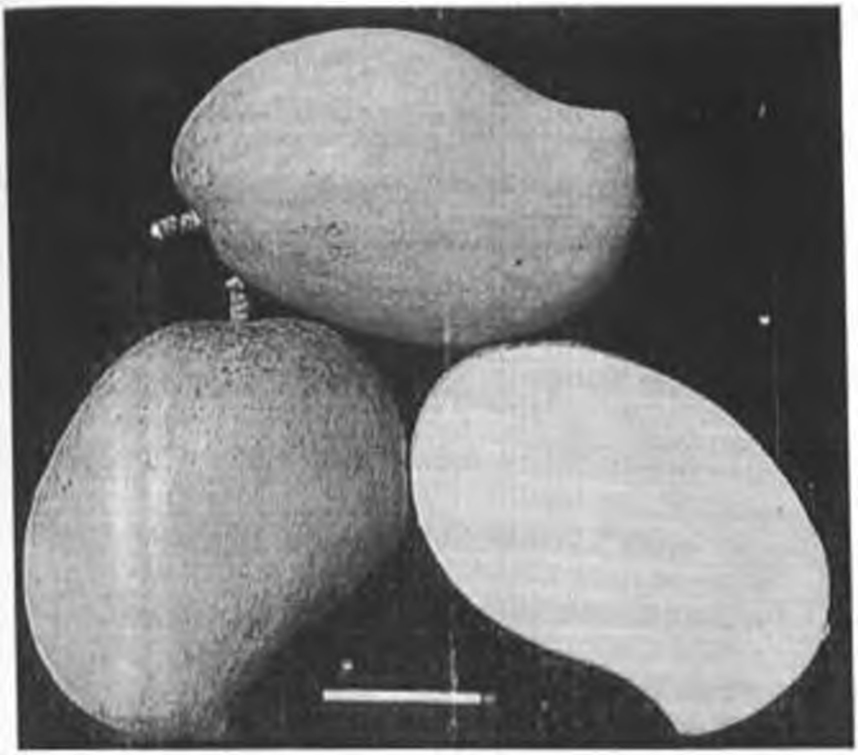

Figure 1: Ngowe variety of mango – cross-sectional and whole view

Source: Griesbach, 2003

The trees are comparatively small and round in shape. Depending on location, harvesting may start in November and continue until March. Yields are medium to high and alternate bearing may occur (Griesbach, 2003).

Advantages:

- good to excellent fruit quality
- moderate tree size
- good shipper

- seed propagation is possible (polyembryonic)

Disadvantages:

- susceptible to powdery mildew
- tendency of alternate bearing

Ngowe is an ideal processing mango, not too fibrous, with high sugar content, good aroma and flavor, high yield, and two production seasons per year. Its mango pulp has the following standard organoleptic properties:

- Bright orange yellow, without any greenish taint
- Characteristic mango flavour. Normal in all aspects with no fermented, off flavor, caramelized or objectionable flavour
- Smooth, pulpy texture, free from any fibrous or stringy particle
- Free from pieces of shell, seeds, any other coarse or hard materials (USAID-KHDP, 2006).

2.6 Knowledge gaps

In Kenya, vitamin A fortification of fruit-based beverages generally, and those of mango specifically, has not been explored. This study sought to increase the information available on the technical and economic feasibility of vitamin A enrichment of mango nectar and its suitability for use as a vitamin A supplement.

CHAPTER THREE STUDY SETTING AND METHODOLOGY

3.1 Study setting

Kangemi Location, situated about 5 km from Nairobi City was taken as the study area. It is a cosmopolitan area; with a population of 82, 964 people and has three sub-locations; namely Kangemi, Gicagi and Loresho. The people of the study area derive their income from salaried employment, operating micro and small-scale businesses and from informal activities such as provision of casual labour, trading, plumbing, masonry and similar activities.

3.2 Research methodology

3.2.1 Study population

Primary school children, from Class 1 to 8 in the government-supported Loresho Primary School, in Kangemi Location were selected for participation in the consumer acceptability testing. The ages targeted were 6 to 15 years. Coming from low-income households most of the primary school children were presumed to be deficient in vitamin A.

3.2.2 Study design

The study involved development of an interventional product – a nutritious product to promote healthy living and contribute to alleviation and prevention of VAD among school children aged 6 – 15 years. Testing consumer acceptance was crucial because the study sought to encourage a behaviour change, i.e. a culture of consuming pure juice or health fruit drinks. Also, this is necessary because there are special considerations when introducing new food products to this particular target age group. The overall study consisted of three main components: determining sources of vitamin A available to the target population; development of an interventional product; and presenting the developed product for consumer acceptability evaluation. The study design employed for the product development component was a **3x3x1 factorial completely randomized experimental design, using three replicates**. These factors were: (i) 3 vitamin A fortification levels (0 %, 20% and 50%); (ii) 3 storage temperature (4°C, 25°C and 38°C); and (iii) 1 packaging material (clear plastic bottle). Three replicates of each treatment were analyzed on a weekly basis for a period of 5 weeks to determine their stability during storage.

3.2.3 Sampling

3.2.3.1 Sample size determination

For the laboratory-based component enough sample of the developed mango nectar was availed to allow for triplicate testing of the various variables of interest for all the sample treatments. Additionally, enough samples were availed for sensory evaluation by the trained panelists as well as for the school-based consumer evaluation. For the consumer acceptability survey, the total number of school children to participate in the study was calculated as follows (Fisher *et al.*, 1991):

$$n = \frac{Z^2 pq}{d^2}$$

Where

n = sample size

Z = the desired confidence level of 95% (1.96:from the tables)

p = 50% (0.5) assumed proportion of the study sample fully accepting the product

$q = 1 - p = 1 - 0.5 = 0.5$

d = the degree of accuracy or precision required (0.05). Thus the sample size n is calculated as follows:

$$n = \frac{1.96^2 \text{ X } (0.5 \text{ X } 0.5)}{0.05^2} = 384.2 \approx 385$$

Therefore, a total number of 385 pupils were targeted. However, after consultation with the school administration, it was suggested and agreed that a single stream, alternating with each class grade (e.g. Class 1 West, Class 2 East and so on) should be used in the survey and thus the total number of children to be targeted emerged as 464.

3.2.3.2 Sampling procedure

Purposive sampling was done to determine the area to be studied – Kangemi. It was purposively selected since it is a low-income area, with a number of public primary schools and also due to its proximity to the area where the product under test was to be developed. Since it is a low-income area and the residents have a low purchasing power, the likelihood of inadequate food and nutrient intake, and consequently VMDs including VAD, was higher. Likewise, Loresho Primary School was selected because the head teacher and school community were receptive and willing to participate in the research; it is close to where the product was being developed and it would therefore be easier to transport the samples to it. Additionally, it was participating in the government's free primary education (FPE) programme and had a school feeding programme. This was significant since this study sought to determine the potential of the developed fortified mango nectar in fitting into ongoing government initiatives aimed at promoting the attainment of universal free primary education and improving nutrition of primary school children. Stratified sampling was done to identify the children who would participate in the study (6-15 years), in the selected school. Then systematic sampling was done to determine the particular students among whom the consumer acceptability survey was conducted (see Fig 3). The inclusion criteria were primary school children: (aged 6-15 years or in Class 1 to 8); with parents in the low-income (socio-economic) class (determined by proxy); from a public primary school that was participating in the FPE programme, with a school feeding programme.

Those excluded from the study were children: at a stage in schooling that was below or above primary school; with parents in mid- to high income (socio-economic) classes (determined by proxy) and attending private primary schools.

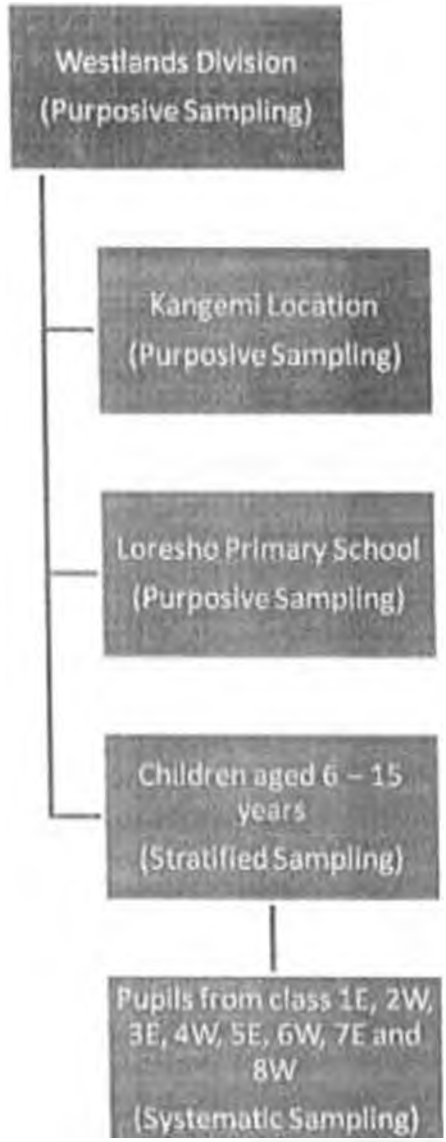

Figure 2: Sampling procedure of the study
Source: Author's conceptualization

3.2.4 Research instruments

i. Key informant interview schedule

A key informant interview schedule (Appendix 1) was prepared and used to collect information on the dietary sources of vitamin A available to and frequency of consumption of these foods by pupils in the school. Additionally (combined with observation), it was used to establish: the beverages available in and around the school compound, existence of a school-feeding programme in the school; sources of vitamin A available to pupils in and around the school and the potential fit of the fortified mango drink in the school feeding programme. This tool also enabled the collection of information on difficulties experienced in providing food to the school children. The key informant interview was also used to determine (by proxy) the socio-economic status of the school children's parents and in turn, inferences on their vitamin A status. The school's headmistress, teachers and the kitchen staff were interviewed. An interview guide was developed and used.

ii. Sensory evaluation questionnaires

Sensory evaluation questionnaires (Appendix 2, 3 and 7) were used to collect information on the organoleptic properties and hence acceptability of the developed mango nectar. The sensory evaluation questionnaires were pretested and improved upon before being used.

3.2.5 Techniques of data collection

The techniques of data collection included: laboratory analysis, sensory evaluation, consumer acceptability evaluation, observation and key informant interviews.

3.2.6 Ethical and human rights considerations

Only food-grade materials were used in preparation of the sensory evaluation samples. The data collection methods were non-invasive and no human rights infringement or violation occurred during the study. A research permit was sought and granted by the Ministry of Education, Science and Technology and permission was obtained from the

Nairobi City Council as well as school authorities to conduct the school-based consumer acceptability evaluation. The enumerator recruited was trained on proper research ethics.

3.2.7 Recruitment and training of sensory evaluation panelists and enumerators

Recruitment and training of sensory evaluation panelists

Twenty healthy persons were selected, screened and trained from the students and staff of the Department of Food Technology and Nutrition to perform the sensory evaluation. However, only ten were used in conducting the sensory evaluation; with the other ten allowing for absenteeism or attrition. The Triangle Test was used in selecting the panelists (See Appendix 2). The selected panelists would later conduct sensory evaluation according to Appendix 3.

Recruitment and training of enumerators

One enumerator was recruited to assist in the school-based consumer acceptability evaluation. Applications were sought from prospective enumerators from a network of professional colleagues. Interviews were conducted and the enumerator who was recruited was a healthy adult, with a tertiary level qualification in a complementary course (Food Production), and had above-average ability to communicate in English and Kiswahili. After recruitment, the enumerator was trained in various research aspects as per the schedule in Appendix 4.

3.3 Data collection

The overall data collection aspects in the study consisted of: determining sources of vitamin A available to the target population; development of an interventional product, and testing its sensory properties and storage stability among trained panelists; and presenting the developed product for consumer acceptability evaluation.

3.3.1 Determining sources of vitamin A available to the primary school children in the study area

A survey was conducted to determine sources of vitamin A available to the primary school children in the study area. The methods of data collection used were observation and interviews. The interview guide used is in Appendix 1.

3.3.2 Development of the mango nectar and fortifying it with vitamin A

3.3.2.1 Development of the mango nectar

Mango nectar was prepared from mango pulp and other ingredients according to the process shown in Fig. 4 and explained below. However, different formulations were tried out and tested by a sensory evaluation panel before the most acceptable formulation was found. Three formulations were tried out.

By definition, mango nectar is produced by mixing the puree or pulp with citric acid, sugar and water; with pulp content varying between 25% and 50%. (Bates *et al.*, 2001) Mango pulp produced from the Ngowe variety was sourced from Kasarani Fresh Ltd – a fruit processor based in Nairobi, Kenya. The pulp was sieved to remove any residual fibrous material and was then blended with sugar, citric acid, potassium metabisulphite and water in varying proportions to determine the best formulation. It was then pasteurized at between 85°C - 90°C and held for 10 minutes. Three formulations were considered and resultant products subjected to preliminary sensory evaluation. These were judged for taste, colour, mouthfeel and overall acceptability.

The first formulation contained 25% pulp. 1% citric acid. 5% sugar and 68.8% water. The preservative (potassium metabisulphite) was added at the rate of 0.2% as per the method of Hashmi *et al.* (2007) and Falade *et al* (2004). The resultant product was found to be unsatisfactory. The comments received were: it was "too watery; "not sweet enough" and had a "tart taste". To improve the product a second formulation was considered and it contained 37.5% pulp, 0.5% citric acid, 10% sugar and 51.8% water. The amount of preservative was retained at 0.2%. This amount of pulp was the mid-point between 25% and 50%. This gave a much more acceptable product; with the comments received being: had a "faint mango flavour"; "increase the mango content"; "good colour but a little faint" and "sweet enough." Thus a third formulation was used, leaving all other ingredients' proportions unchanged and varying only those pulp and water to give 50% pulp and 39.3% water. This product was found to be "excellent" in taste, colour, mouthfeel and overall acceptability. Thus the third formulation was selected as being the best.

Also different types of packaging were evaluated for their suitability and to select the best package. These were tetrabrik ®, plastic bottle, PET bottle, glass bottle and plastic pouch. They were evaluated for cost, attractiveness, capacity, convenience in handling and distribution, adaptability to small-scale (low capital intensive) processing operations and ability to withstand pasteurization conditions.

The manufactured mango nectar was treated as follows:

i. Fortification with vitamin A at three levels: control (0 %), 20% and 50% of the vitamin A RDA of children aged above 6 years

ii. Packaging the resultant product in clear plastic bottles

iii. Storage of the fortified packaged product at different temperatures, representing chilled storage, the median and highest average ambient conditions in Kenya, respectively (4°C, 25°C and 38°C)

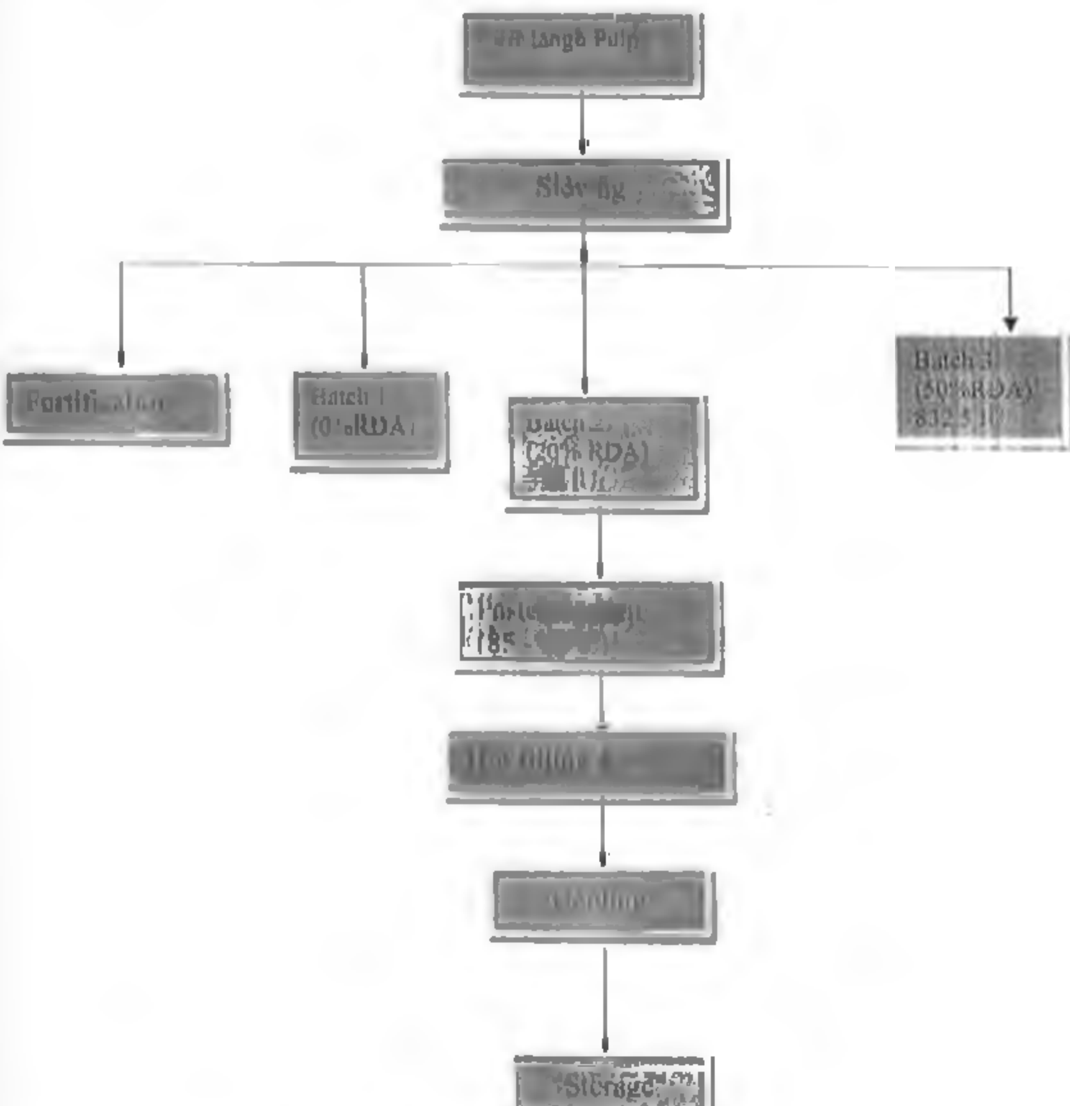

Figure 3: Process flow chart of mango nectar production
Source: Author's Conceptualization

3.3.2.2 Fortification of the mango nectar with vitamin A (Dry Vitamin A Acetate Type 325 CWS)

Vitamin A, in the form of Dry Vitamin A Acetate Type 325 CWS sourced from DSM Nutritional Products Ltd, Switzerland was added to the best product (see Appendix 6 DSM Dry Vitamin A Acetate Type 325 CWS Product Specification Sheet). This is the form that was recommended for use in beverages by DSM Nutritional Products Ltd. Three levels – control, 333 IU (100 RE) and 832.5 IU (250 RE); representing 0%, 20% and 50% of RDA of children aged 6 years and above, respectively, were added to three separate batches of the developed product. During food fortification, the amount recommended is usually 15-20% RDA of the given nutrient; assuming that the rest comes from food sources. Additionally, an overage of 40% was calculated and added to each of the batches excluding the control. This was to cater for losses during processing. The product was then hot-filled into sterilized bottles, ensuring that the air in the head space was expelled to create a sterile head space, and the bottles were then sealed with screw-on caps. The bottles were turned upside-down to ensure adequate sterilization of the screw-on bottle caps. This gave three treatments: control, with no vitamin A added); with 20% of RDA vitamin A added and with 50% of RDA vitamin A added. Immediately after sealing the bottles, the products were cooled to room temperature in a water bath. The products were then stored at different temperatures: 4°C, 25°C and 38°C and samples were subsequently collected for both laboratory and sensory evaluation.

Different types of packaging were evaluated for their suitability and to select the most suitable package. These were tetrabrik ®, plastic bottle, PET bottle, glass bottle and plastic pouch. They were evaluated for cost, attractiveness, capacity, convenience in handling and distribution, adaptability to small-scale (low capital intensive) processing operations and ability to withstand pasteurization conditions.

The physicochemical attributes of the product which were measured were pH, °Brix, total titratable acidity, vitamin A and vitamin C content. To determine the microbiological safety of the products, they were analyzed for presence/absence of coliforms, as well as yeasts and moulds. Sensory evaluation was used to determine the developed product's attributes of taste, colour, mouth-feel and overall acceptability.

3.3.2.3 Determining the biochemical quality of the product

3.3.2.3.1 Determination of the pH

The pH of the product was measured using a pH meter (model E-520). Ten ml of the sample were pipetted into a beaker. The probe of the pH meter was then placed in the sample and a reading of the product's pH obtained. This was done in triplicate

3.3.2.3.2 Determination of soluble solids content (°Brix)

To determine the product's soluble solids content (°brix), a small amount of each of the samples was placed on a hand refractometer (Abbe 60 series) and the reading taken at 20°C. The temperature of each sample was brought to 20°C before the reading was taken. This was done in triplicate.

3.3.2.3.3 Determination of the titratable acidity

The product's titratable acidity was measured according to the method used by the AOAC (1995). Ten ml of fruit juice was pipetted into an Erlenmeyer flask, and then it was heated until boiling began. To it, was added 50 ml of carbon dioxide-free distilled water and 1 ml of phenolphthalein indicator. The titration was carried out, by means of 0.1 N-NaOH with continuous swirling of the flask until there was the appearance of a distinct red colour. The acidity was calculated in this way: 1ml of 0.1 N-NaOH represents 10 milli-equivalents of acid in a litre. The acidity was expressed in milli-equivalents of acid in a litre or as a percentage of citric acid.

3.3.2.3.4 Determination of vitamin C (ascorbic acid) content

The determination of vitamin C (ascorbic acid) content was done using the 'dye' method.

Ten ml of the mango nectar were mixed with 60 ml of 5% trichloroacetic acid solution. The mixture was quickly filtered through glass wool into a 100 ml volumetric flask and filled to the mark with the 5 % trichloroacetic acid solution. Ten ml of this solution was titrated with standardized dichlorophenol-indophenol reagent. The dichlorophenol-indophenol reagent was standardized using ascorbic acid standard solution. The amount of ascorbic acid in the sample was expressed as mg ascorbic acid per 100 ml of sample.

3.3.2.3.5 Determination of vitamin A (retinol) content and of beta-carotene content

Both vitamin A and beta-carotene content of the sample were determined using HPLC equipment (Bureau and Bushway, 1986; Bushway, 1985; Bushway and Wilson, 1982). The HPLC equipment used was Agilent 1100 Series. For the analysis only HPLC-grade reagents were used. The mobile phase used was acetonitrile-tetrahydrofuran (THF) stabilized with butylated hydroxytoluene (BHT)-water in the ratio of 85:12.5:2.5 v/v/v; pumped at a flow rate of 2.0 mL/minute. The column used was Agilent Zorbax Eclipse XDB C_8, 4.6 mm x 150 mm.

Preparation of standards

Internal standard solutions for the calibration of the equipment were prepared from pure beta-carotene and retinol standards obtained from Sigma-Aldrich Company of Germany. Ten µl of each of the working standards representing concentrations of 1 PPM to 5 PPM were injected into the HPLC equipment, each time the analysis was conducted

Analysis of samples

Ten ml of the sample were weighed and extracted with 125 ml tetrahydrofuran (THF), 5.0 g anhydrous sodium sulphate, and 1.0 g magnesium carbonate in a 1-L mechanical blender at a moderate speed for 5 minutes. The mixture was then vacuum-filtered through a Buchner funnel fitted with Whatman no. 42 filter paper. The filter cake was re-extracted to remove all carotenoids. The filtrates were combined and brought to a volume of 500 ml with THF. An aliquot of 100 ml was transferred to a 250-ml round-bottom flask and evaporated to dryness, using a rotary evaporator at 40°C. The residue was redissolved in 10 ml THF with the aid of sonication and 20µl of each sample extract was injected into the HPLC equipment. Quantification was done with the detection set at 470 nm for beta carotene and at 325 nm for retinol, respectively.

3.3.2.4 Enumeration and confirmation of yeasts and moulds

reagents were used. The mobile phase used was acetonitrile-tetrahydrofuran (THF) stabilized with butylated hydroxytoluene (BHT)-water in the ratio of 85:12.5:2.5 v/v/v; pumped at a flow rate of 2.0 mL/minute. The column used was Agilent Zorbax Eclipse XDB C_8 4.6 mm x 150 mm.

Preparation of standards

Internal standard solutions for the calibration of the equipment were prepared from pure beta-carotene and retinol standards obtained from Sigma-Aldrich Company of Germany. Ten µl of each of the working standards representing concentrations of 1 PPM to 5 PPM were injected into the HPLC equipment, each time the analysis was conducted.

Analysis of samples

Ten ml of the sample were weighed and extracted with 125 ml tetrahydrofuran (THF), 5.0 g anhydrous sodium sulphate, and 1.0 g magnesium carbonate in a 1-L mechanical blender at a moderate speed for 5 minutes. The mixture was then vacuum-filtered through a Buchner funnel fitted with Whatman no. 42 filter paper. The filter cake was re-extracted to remove all carotenoids. The filtrates were combined and brought to a volume of 500 ml with THF. An aliquot of 100 ml was transferred to a 250-ml round-bottom flask and evaporated to dryness, using a rotary evaporator at 40°C. The residue was redissolved in 10 ml THF with the aid of sonication and 20µl of each sample extract was injected into the HPLC equipment. Quantification was done with the detection set at 470 nm for beta-carotene and at 325 nm for retinol, respectively.

3.3.2.4 Enumeration and confirmation of yeasts and moulds

Samples were analysed for growth of yeasts and molds as assurance of the product's quality and safety. Ten ml of sample were added to 15 ml of potato dextrose agar and incubated at 45°C for 48 hours (Harrigan and McCance, 1976).

3.3.2.5 Enumeration and confirmation of coliforms

Samples were analyzed for the presence of coliforms as assurance of the product's quality and safety. Ten ml of sample were added to 15ml of violet-red bile agar and incubated at 30°C for 24 hours.

3.3.3 Determining the sensory properties of the fortified mango nectar by using a trained sensory evaluation panel

Sensory evaluation was used to determine the developed product's attributes i.e. taste, colour, mouth-feel and overall acceptability.

3.3.3.1 Recruitment and training of the sensory evaluation panel

The potential panelists, drawn from the University of Nairobi's Food Technology and Nutrition Department were approached individually and informed about the proposed study and asked if they would be interested in participating in sensory evaluation of the product to be developed in the course of the research project. Twenty five panelists were approached and twenty accepted. In order to select those who would participate in the panel, discriminatory evaluation using the triangle test was used. The triangle test was also used for training and monitoring performance of the sensory evaluation panelists. Each of the twenty panelists was presented with three coded samples, in small plastic cups: two of the samples were similar and one was different. The samples were distilled water and 10% sucrose solution.

The samples were presented in a triangle format. The panelists were asked to identify which sample was different. The panelists who initially successfully identified the odd sample were recruited into the sensory evaluation panel. These panelists were then trained in the quality attributes (colour, taste, mouthfeel and overall acceptability) of the product developed.

This method was employed since the panelists would be later required to determine the effect of various ingredient substitutions on the product's organoleptic quality in the course of the product's development. The tests were conducted according to the guide in Appendix 2, and data collected was analyzed.

3.3.3.2 Sensory evaluation of the developed fortified mango nectar

Both the freshly prepared and stored samples of the developed fortified mango nectar were subjected to sensory evaluation by the trained panelists. The evaluation was conducted in a well lit and quiet room. Sensory responses were used to determine the effect of vitamin A fortification levels on the organoleptic properties of the product as well as the effect of the interaction of the fortified product with both packaging material and storage temperatures. A seven-point Hedonic Scale was used to assess the overall acceptability, colour, taste (flavour and aroma) and mouth-feel of the resultant product by 10 trained panelists. Also a triangle test was used to determine panelists' ability to cups: two of the samples were similar and one was different. The samples were distilled water and 10% sucrose solution.

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The samples were drawn from each of the storage conditions, once every week for a five-week period, to evaluate the fortification, packaging and storage success. On the day of testing the sample temperatures were also equilibrated and all samples were served at a temperature of 20°C because taste sensitivity is greatest at temperatures of between 20°C and 30°C. All panelists were asked to judge each of the samples and rate it according to the scale provided in the sensory evaluation form (see Appendix 2). Water was provided for the panelists to rinse their mouths after evaluating each sample. Based on the results of the sensory evaluation by the trained panel, the product treatment (in terms of vitamin A fortification) that was identified as the best was further developed for the consumer acceptability evaluation.

3.3.4 Determining the storage stability of the developed mango nectar fortified with vitamin A

The stored samples of the developed product were then analyzed on a weekly basis, for a period of 5 weeks to determine their stability during storage. Changes in the product's quality attributes were determined through laboratory analysis and sensory evaluation. The product attributes measured were pH, °brix, total titratable acidity, vitamin A and vitamin C content; and taste, colour, mouth-feel and overall acceptability.

Based on the results of the sensory evaluation by the trained panel, the product treatment that was identified as the best was further developed for evaluation by the children. The methods used for these evaluations are as outlined in sections 3.3.2.3 and 3.3.3 above.

3.3.5 Determining the acceptability of the developed vitamin A fortified mango nectar among its target consumers (primary school children)

A fresh batch of the final formulation of the product was prepared one day before the scheduled consumer acceptability evaluation. This product was stored at chilled temperatures overnight and the next morning was removed from the storage and kept at ambient temperatures. It was then packed into cartons and transported to Loresho Primary School - the chosen site of the consumer acceptability survey. The product was then served to the pupils at ambient temperatures, in the semi-clear plastic bottle packaging since feedback on the packaging was also going to be collected. The product was served in this way also to ensure that the product was being served in the same way as it would be found at the point of distribution. The product was also served at lunch time – to determine how well it would fit into the pupils' normal lunch time routines, and also within a school feeding programme. The pupils were presented with the product and given a brief introduction to both the product and purpose of the consumer survey. They were then taken through the sensory evaluation questionnaire (see Appendix 7) and thereafter allowed to freely examine and evaluate the product for its taste, colour, mouth feel and overall acceptability (Fig. 5 below). The pupils were assisted to correctly score the products using the 7-point Hedonic Scale. The scores for these attributes gave an indication of the respondents' acceptance or rejection of the product.

The pupils were also asked to respond whether or not they like the product and if they would ask their parents to buy the product for them or buy it for themselves using their lunch or snack money.

3.3.6 Cost of Product

The cost of product was based on these categories: ingredients, fortificant, packaging, other costs (labour, and energy). Three different formulations were prepared and costed to determine the best product.

To determine the cost of fortificant for a 100-litre batch of product involved first calculating the amount of fortificant required for the batch of product; calculated as below:

Amount of vitamin A fortificant in 250-ml of product was 333 IU (corresponding to 20% RDA) plus a 40% overage. Therefore the total amount of vitamin A to be added to product

= 140% X 333IU

= 466.2 IU in a 250-ml bottle (1 serving)

But 100 litres corresponds to 400 bottles (400 servings), therefore the amount of fortificant required in 100 litres

= 466.2 X 400 IU

= 186, 480 IU

But 1g DSM Dry Vitamin A Acetate Type 325 CWS contains 325,000 IU (see Appendix 4). Therefore the amount of fortificant required for 100 litres of the product

= 186, 480/325,000 g

= 0.574 g

To determine the cost of fortificant for a 100-litre batch of product

1,000 g of DSM Dry Vitamin A Acetate Type 325 CWS cost € 46.58

Therefore the cost for 0.574g

= € (0.574X46.58)/1000

= €0.027;

In KSh, at the prevailing exchange rate at time of study (€ 1= KSh 90.00)

= KSh 2.40

Therefore cost of fortifying 100 litres of mango nectar

= KSh 2.40

3.4 Data Quality Control

The questionnaires were received from the enumerator and respondents and were then checked at the end of the evaluation, to identify any sources of error. Also, outliers were identified, noted and excluded from further analysis, where the source of the error could not be identified at that time.

3.5 Data Management and Analysis

Data management

Data entry templates were developed to ensure streamlined recording of observations. Questionnaires to be used were pretested and were subsequently modified according to the feedback received. Data was then collected and used to complete the data entry templates. The completed questionnaires were stored in a safe place that was also fire- and water proof, awaiting data entry.

Data analysis

Data collected was analyzed using Statistical Package for Social Scientists (SPSS) version 16.0 and presented in tables and charts. Analysis of Variance (ANOVA) and the Mann-Whitney test were used to conduct statistical analyses, and the p value was set at P=0.05.

CHAPTER FOUR RESULTS

4.1 Sources of vitamin A available to the primary school children in the study area

Information gathered from observations of the school and the pupils as well as responses to the key informant interview questions revealed that there was an ongoing school feeding programme and several beverages were available, in and around the school, and they contributed in some way to the dietary vitamin A of the pupils.

Information on the school feeding programme at Loresho Primary School was gathered to determine the adequacy of the school meals in providing vitamin A on a daily basis to the school pupils.

Seventy five percent of the pupils at the school were found to come from low-income households and thus it was inferred that their diets were similar to those consumed by families in similar circumstances, which had been found to be low in souces of retinol. Moreover, most could not afford the KSh 30.00 per meal charged by the school in the school-feeding programme. Only 100 out of 974 pupils enrolled at the school took part in the school-feeding programme, which was open to all pupils who could afford to pay for the meals. The meals served as part of the school feeding programme were prepared in the school kitchen. The menu of the meals in the school feeding programme is given below (Table 1). Beef was consumed only once a week, while most of the other meals were vegetarian in nature.

Table 1: Menu of meals served in the school-feeding programme at Loresho Primary School

Day of the week	Meal served
Monday	Rice, beans and potatoes; prepared with carrots
Tuesday	*Ugali*, beef stew and cabbage/kale/spinach
Wednesday	Green grams stew with *chapati*
Thursday	Fried rice prepared with potatoes, carrots, peas, sweet pepper, tomatoes and onions
Friday	*Githeri* (mixture of maize and beans) prepared with peas, carrots and potatoes

Note: *Ugali* is a stiff porridge made from maize flour; *chapati* is a type of flat bread made from mainly from wheat flour and fried on a flat pan while *githeri* is a mixture of maize and beans cooked together, usually boiled first, and may later be fried

The rest of the pupils either brought packed lunch from home or bought snacks from the school canteen or nearby shops. There was no milk or other vitamin A-rich drink provided by the school and the beverages consumed by the pupils were mainly brought from home, or bought from the school canteen and nearby shops (Table 2).

Table 2: Results of survey of soft drinks sold in and around Loresho Primary School

Product name	Manufacturer	Packaging Type	Fortified/Enriched		Capacity	Price* (KSh)
			Nutrient	Amount listed		
Assorted flavoured drinks	Various	PET bottles, glass bottles	-	-		
"Healthy" Fruit Drinks						
Fruit Burst (contains mango)	Del Monte Ltd	Tetrapak	Vitamin C	24 mg/100 ml	250 ml	35.00
Mango Juice Blend	Del Monte Ltd	Tetrapak	-	-	200 ml	25.00
Jaffa Gold Tropical Mango Nectar	Miritini (K) Ltd	Tetrapak	Vitamin C	15 mg/100ml	250 ml	25.00
Fruit Paradise Refreshing Mango Juice	Twin Oaks Ltd	Tetrapak	Vitamin C	11.2 mg/100ml	250 ml	35.00
Pick n Peel Mango	Kevian (K) Ltd	Tetrapak	-	-	250 ml	34.00
Splash Mango	Britania Allied Industries Ltd (Uganda)	Tetrapak	Vitamin C	9.9 mg/100ml	250 ml	30.00
Afia Multivitamin Drink (contains orange)	Kevian (K) Ltd	PET bottles	Vitamins A, C, E	Not stated	500 ml	31.00
Ceres Mango	Ceres Fruit Juices (SA) Ltd	Tetrapak	-		1 litre	135.00
Kenylon Mango	Kabazi Canners Ltd	Tetrapak	-		1 litre	110.00
Minute Maid Orange-Mango Blend	Coca Cola Company	Tetrapak	-		1 litre	125.00
Vitrac Mango Nectar	Hero Vitrac Company (Egypt)	Tetrapak	-		1 litre	105.00

Note: * Prices at time of study (April – June 2007).

4.2 Development of fortified mango nectar

4.2.1 Determining the best product formulation and packaging

The inputs for developing the fortified mango nectar were: ingredients (including vitamin A fortificant), equipment, technological expertise, labour and energy. The output was an attractive, healthy, safe, stable and highly acceptable fortified product that can be used as intervention in the alleviation or prevention of VAD among primary school children.

To get the most acceptable product formulation, three formulations of the product were made and evaluated in the course of the study; varying the ingredients. The packaging material was also evaluated.

The first formulation contained 25% pulp, 0.5% citric acid, 10% sugar, 69% water with 0.2% potassium metabisulphite. The judges found the resultant product to be unsatisfactory. They commented that it was "too watery" and "did not have enough of a mango taste" . The second formulation considered contained 37.5% pulp, 0.5% citric acid, 10% sugar . 51.8% water with 0.2% potassium metabisulphite . This formulation gave a much more acceptable product; with the comments received being. had a "faint mango flavour"; "increase the mango content"; "good colour but a little faint" and "sweet enough." The third formulation contained 50% pulp , 0 .5% citric acid, 10% sugar , 39.3% water with 0.2% potassium metabisulphite. This product was found to be "excellent" in taste, colour, mouthfeel and overall acceptability. Thus the third formulation was selected as being the best Costing of the three formulations was also done to determine the best and most cost-effective formulation. An expression for determining the cost of the formulation, for a 100-litre batch (excluding the fortification), was derived as:

$$y = 100p + 770$$

Where y = cost of 100 litres of product in KSh

p = cost of mango pulp in KSh

and 770 = cost of all other ingredients in KSh (remained constant)

but $p = (x\% * 100)$

where x% = percentage of mango pulp in product

therefore $p = x\% * 100$; 100 is the cost of 1 litre of mango pulp

Substituting x% with 25%, 37.5% and 50% in the above expression gave these values: KSh 3,270, KSh 4,520 and KSh 5,770, respectively.

An evaluation of the packaging was done and the results are given in Table 3 below

Table 3: Results of the evaluation of packaging types available for the mango nectar

Packaging Type	Cost/price*	Flexibility or adaptability to small-scale operations	Attractiveness	Available capacities	Other attributes
Clear glass bottle	10.00	Not very good; bottling equipment or line required for capping	Very good; product is clearly visible	300 ml	Reusable/returnable; can withstand hot-filling
Clear plastic bottle	4.80	Good	Very good; product is clearly visible	250 ml	Can withstand hot-filling
Clear PET bottle	6.50	Good	Very good; product is clearly visible	250 ml	Could not withstand hot-filling
Tetrabrik® (Tetrapak)	n.a.	Not very good; complex equipment or line required for filling and sealing	Good but requires branding; product not visible	200 ml; 250 ml;	Can withstand hot-filling, offers better protection for product
Plastic pouch	1.00	Fair; filling may be by hand; equipment required for sealing	Good; if opaque may require branding and product not visible	500 ml	Can withstand hot-filling; offers better protection for product, if opaque

Note: * Prices at time of study (April – June 2007). Prices could not be availed for tetrabrik® packaging as quotes and services are provided for prospective commercial operations (1,000 litres and above) only (not for research) and include branding of the packaging

Based on the above results, the best packaging was found to be clear plastic bottles they were attractive, affordable, recyclable, adaptable to small-scale processing operations and could be easily packed into cartons for dispatch.

The best processing conditions were found to be pasteurization and holding for 10 minutes at 85°C – 90 °C, followed by cooling.

4.2.2 Fortification of the mango nectar with vitamin A (dry vitamin A acetate type 325 CWS)

The product was fortified with 333 IU retinol (in form of Dry Vitamin A Acetate Type 325 CWS), plus a 40% overage, was found to be the best, as judged by the sensory evaluation panelists, and according to purposes of study.

4.2.3 The biochemical quality of the fresh vitamin A fortified mango nectar

The notations of the samples were: Sample 1 (S1): stored at 4°C; Sample 2 (S2): stored at 25°C and Sample 3 (S3): stored at 38°C. The results of the biochemical analysis of the freshly prepared product were as shown in Table 4 below.

Table 4: Biochemical properties of the fresh fortified mango nectar

Parameters					
pH	°Brix	TTA (% citric acid)	Vitamin A content (IU)*	Vitamin C content (mg/100 ml)	Beta-carotene content (µg/100 ml)
3.40	17	0.41	333	14.0	95

*Note: 1 RE = 3.33 IU retinol

4.2.4 Microbiological quality of the fortified mango nectar

There was no observed growth of coliforms, yeast or mould when the freshly manufactured product was inoculated into the corresponding media and incubated (Table 5 below). Likewise during storage over a five-week period, at 4 °C, 25°C and 38 °C, there was also no observed growth of microbes.

Table 5: Microbiological properties of the fresh fortified mango nectar

Coliforms	Yeast and moulds Log10CFU/100ml
-ve	Nil

4.3 Sensory evaluation of the fresh fortified mango nectar trained sensory evaluation panel

4.3.1 Recruitment and training of the sensory evaluation panel

Eighteen out of 20 potential panelists passed the initial screening test by correctly sensing the odd samples, and in addition had an early and correct recognition of the taste of the odd samples. They thus qualified as panelists with the most acute sense of taste. The 18 were recruited to cater for any absenteeism or attrition over the study period, however, 10 were selected to take part in the sensory evaluation, and there was no absenteeism

4.3.2 Sensory evaluation of the developed fortified mango nectar

Four attributes (colour, taste, mouthfeel and overall acceptability) represented the developed fortified mango nectar's sensory profile, and the results are shown in Table 6 below.

Table 6: Sensory properties of the fresh fortified mango nectar

Sensory Attribute	Mean Score
Colour	6.9
Taste	6.9
Mouthfeel	6.8
Overall Acceptability	6.9

Note: Observations of 10 judges were recorded.

4.4 The storage stability of the developed mango nectar fortified with vitamin A

The notations of the stored samples were: Sample 1 (S1): stored at 4°C; Sample 2 (S2): stored at 25°C and Sample 3 (S3): stored at 38°C.The product samples were analyzed for changes in pH, °brix, total titratable acidity, vitamin A and vitamin C content; and taste, colour, mouth-feel and overall acceptability. The results are presented in the following sections.

4.4.1 Changes in the biochemical properties of the fortified mango nectar during storage

4.4.1.1 Ascorbic Acid

Fig. 4: below shows the changes in the ascorbic acid content of the mango nectar during storage.

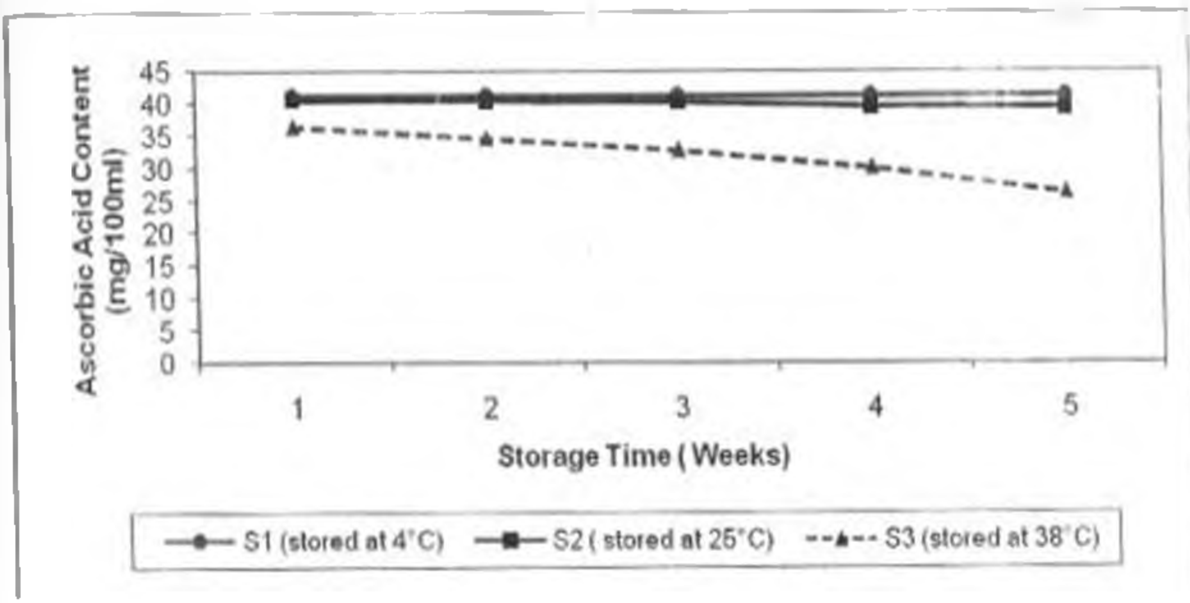

Figure 4: Effect of storage temperature on ascorbic acid content of the product

4.4.1.2 Titratable acidity

Fig.5 below shows the changes in the titratable acidity of the mango nectar during storage.

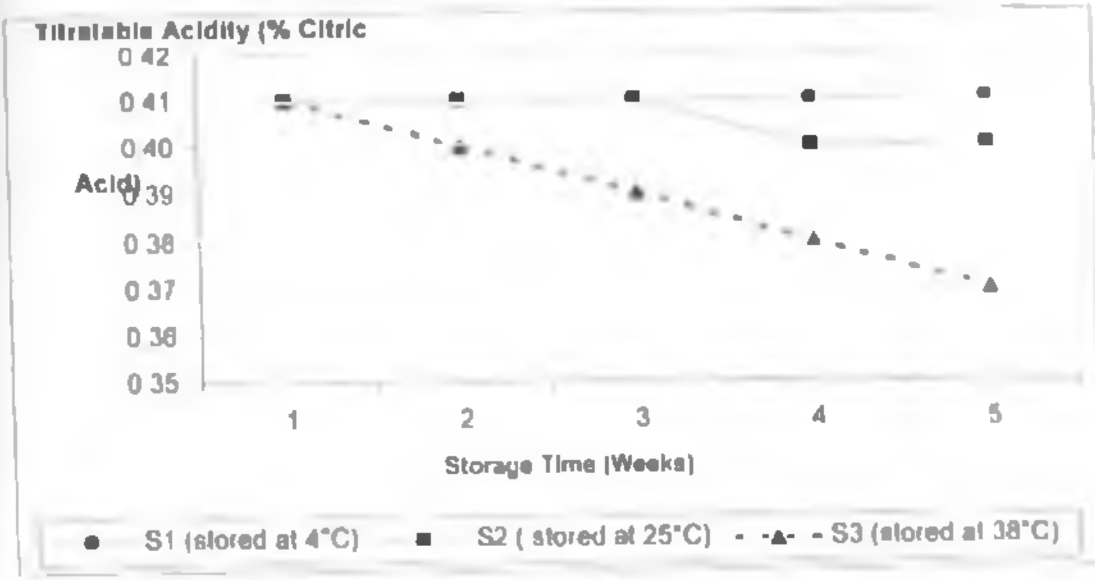

Figure 5: Effect of storage temperature on titratable acidity of the product

4.4.1.3 pH

Fig. 6 below shows the changes in the pH of the mango nectar during storage.

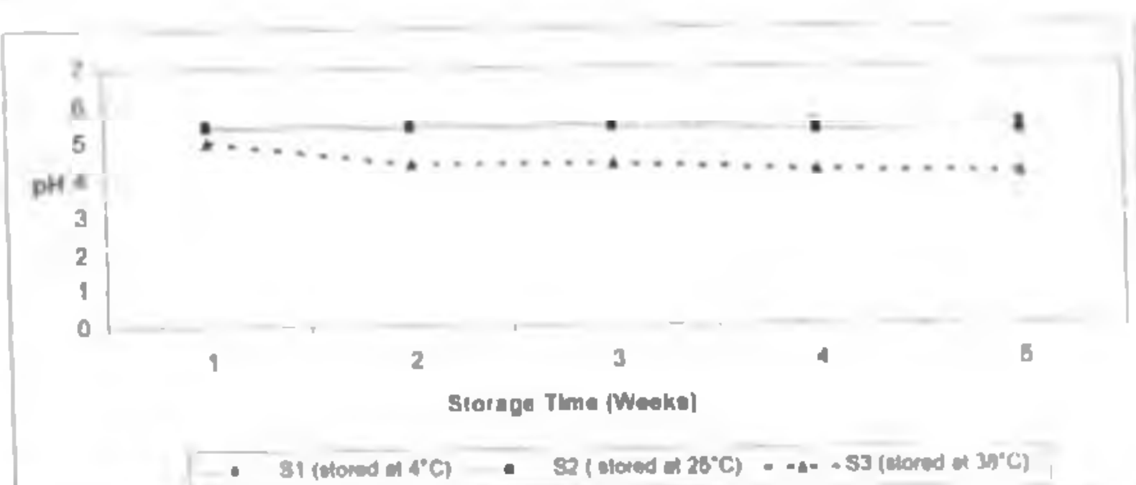

Figure 6: Effect of storage temperature on pH of the product

4.4.1.4 Soluble Solids Content (°Brix)

Fig. 7 below shows the changes in the soluble solids content of the mango nectar during storage.

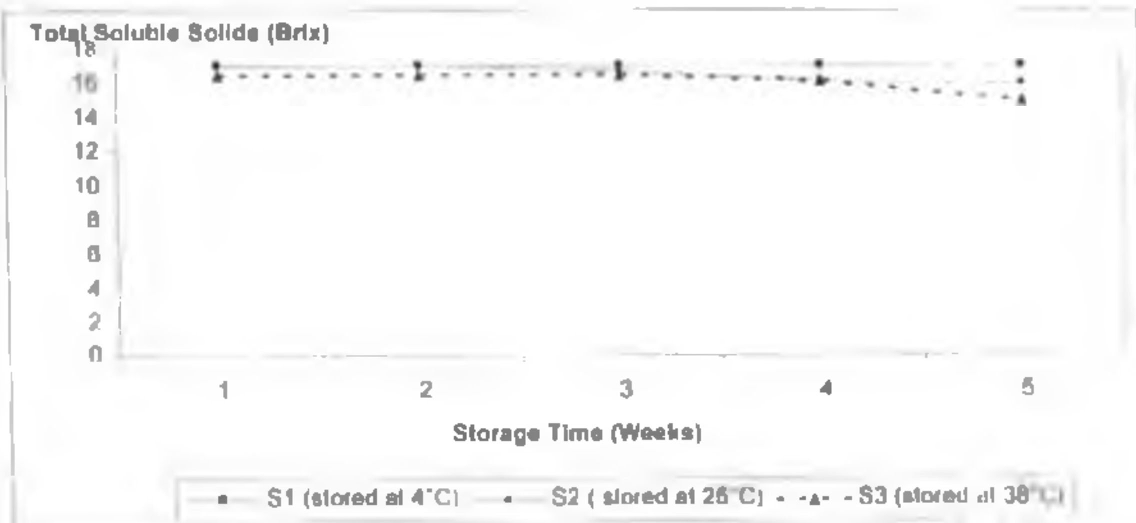

Figure 7: Effect of storage temperature on soluble solids of the product

4.4.2 Changes in vitamin A content of the fortified mango nectar during storage

The results of changes in the vitamin A content of the mango nectar during storage are shown in Fig.8 below.

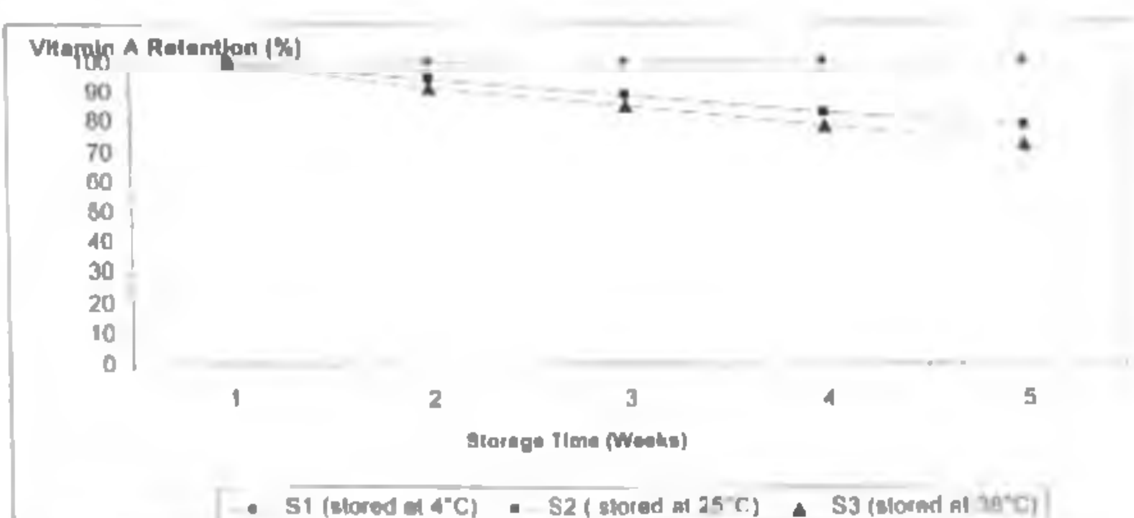

Figure 8: Percentage retention of vitamin A during storage

4.4.3 Changes in beta-carotene content of the fortified mango nectar during storage

Fig.9 below shows the changes in the beta-carotene content of the mango nectar during storage.

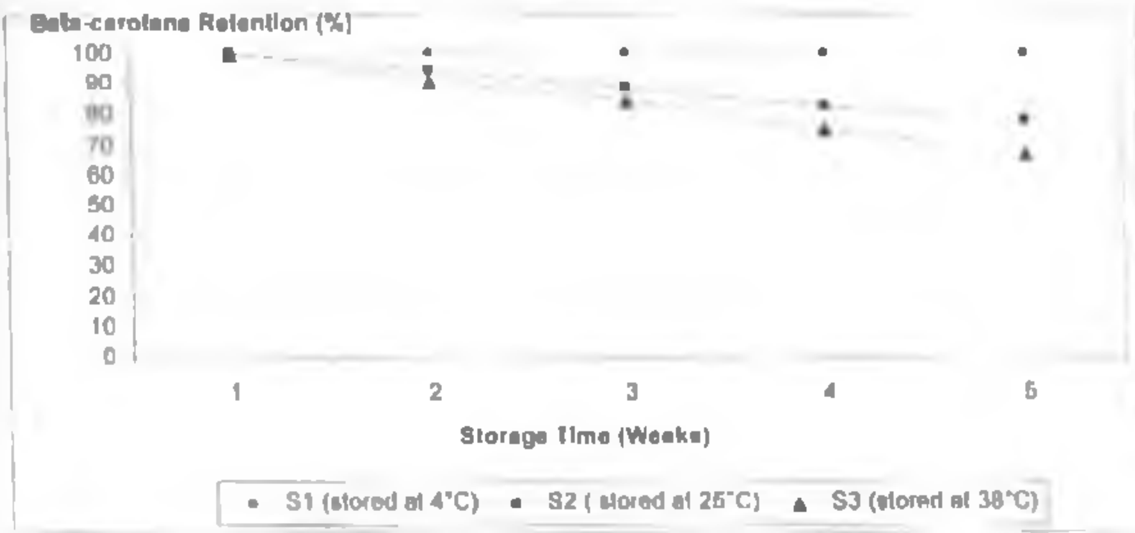

Figure 9: Influence of storage temperature on beta-carotene content

4.4.4 Changes in the sensory properties of fortified mango nectar during storage

4.4.4.1 Colour, taste, mouthfeel and overall acceptability

The samples were evaluated and scored for colour on a weekly basis. As the temperature and time increased, the scores for colour, taste, mouthfeel and overall acceptability decreased (Table 7). These scores remained unchanged for the sample at 4°C (S1).

Table 7: Influence of storage time and temperature on sensory properties of the product

Storage time (weeks)	Mean sensory evaluation scores by panelists											
	Taste			Colour			Mouthfeel			Overall acceptability		
	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3
1	6.9	6.9	4.8	6.9	6.9	5.7	6.8	6.8	4.9	6.9	6.9	4.9
2	6.9	6.4	4.6	6.9	6.9	4.8	6.8	6.8	4.6	6.9	6.4	4.6
3	6.9	6.4	3.8	6.9	6.7	3.9	6.8	6.7	3.8	6.9	6.4	3.8
4	6.9	6.4	3.3	6.9	6.5	3.3	6.8	6.5	3.3	6.9	6.4	3.3
5	6.9	5.6	2.8	6.9	5.9	2.8	6.8	5.9	2.8	6.9	6.4	2.8

Source: Computation based on the primary data

4.5 Consumer acceptability evaluation

4.5.1 School composition

At the time of the study there were 974 pupils registered at Loresho Primary School. Of these, 344 took part in the school-based consumer evaluation, representing classes 1-3 and 5-8. The class 4 pupils who had been identified to also participate in the evaluation were away on a school trip. The number of females that took part was 180 (52.3%) while males were 164 (47.7%) (see and the ages of the children ranged from 6 to 18 years (Table 8).

Table 8: Distribution of surveyed pupils by age and gender

Age (in years)	Gender	
	Male	Female
6-8	45	52
9-11	44	39
12-14	65	83
15-17	10	5
18+		1

Source: Computation based on the primary data

4.5.2 Consumer acceptance of the product

The product aspects that were evaluated by the consumers were: sensory properties (colour, taste and overall acceptability), acceptance (price; "like product"; "would buy/ask parents to buy product") and other (e.g. capacity and attractiveness of packaging). The product was received with a lot of enthusiasm and generally received high scores for the product aspects under test, as seen from the sections below

4.5.2.1 Sensory evaluation of the product by consumers

Table 9 gives the scores for colour, taste and overall acceptability as evaluated by the consumers.

Table 9: Sensory evaluation scores by consumers

Colour	Taste	Overall acceptability
6.75 ± 0.67	6.65± 0.80	6.50 ± 0.9

Note: Average scores for 344 pupils; computation based on the primary data

Majority of the pupils sampled (85.8 %), gave a colour score of 7, which corresponded with 'like very much'. Similarly, 77.0% scored the product's taste as 7, which corresponded to 'like very much'. They also reported that they liked the mango flavour of the product. Also, 75.9 % of the pupils scored the product's overall acceptability as 7.

4.5.2.2 Product's acceptance among consumers

The surveyed pupils were also required to state whether or not they liked the product. Three hundred and thirty nine (98.5%) confirmed that they liked the product while 5 (1.5%) did not like the product. Similarly, 98.5% confirmed that they would buy or ask their parents to buy the product at while 1.5% would not; at a product price of between KSh 20-25.

Table 10: Product acceptance among consumers

Like product	Don't like product	Would buy product	Would not buy product
98.5%	5 %	98.5%	5 %

Source: Computation based on the primary data

Additionally, of the 344 pupils surveyed, only 3 (0.87%) felt that the capacity of product's package (250 ml) was inadequate and should be increased to 500 ml. All the pupils liked the presentation of the product very much and found the clear plastic packaging attractive.

CHAPTER FIVE DISCUSSION

5.1 Sources of vitamin A available to the primary school children in the study area

The survey of the foods and drinks consumed by the pupils at the school showed that few of those foods and drinks were rich in vitamin A and those that had considerable amounts were not consumed in adequate amounts. For instance, in the school feeding programme, beef was consumed only once a week, while most of the other meals were vegetarian in nature (see Table 1). Based on previous research work done in Kawangware, Mathare and Embu, it was inferred that the consumption of animal source vitamin A rich foods was low and as such not capable of providing the target groups vitamin A requirements (Kamau 2004; Van't Riet *et al.*, 2001; Bwibo and Neumann, 2003).

5.2 Development of the mango nectar and fortifying it with vitamin A

It was necessary to develop safe, stable, affordable and acceptable product, and the process employed ensured that it was possible to trace the vitamin A keeping quality and assure that the nutrient continued to exist in the required amounts.

5.2.1 Optimizing the best product formulation and packaging

The product formulation that was used gave a product that was attractive, healthy, safe, stable and highly acceptable. The best packaging was selected for its attractiveness, convenience, affordability, recyclability, adaptability to small-scale processing operations and ease of packing into cartons for dispatch.

The amount of fruit pulp used (50%) contributed to the product's stability since no artificial stabilizers or thickeners were added to the product, so as to give a more natural product. The proportion of sugar and citric acid added gave the best flavour of the product in terms of sweetness and tartness, as associated with mango fruit drinks. The quantities of the preservative and citric acid used together with the pasteurization regimes employed gave a product which was microbiologically stable with no presence of coliforms, yeasts, moulds or other bacteria. This was consistent with results found by Hashmi *et al*. (2007). The addition of citric acid to lower pH also lowers the heat treatment requirements in processed fruits and vegetables (Bates *et al*., 2001)

5.2.2 Fortification of the mango nectar with vitamin A (Dry Vitamin A Acetate Type 325 (WS)

The average RDA value of 500 RE was arrived at by taking the average of the upper limit of the RDAs of children falling within the primary school age group: for both males and female aged 6 – 10 years, the RDA ranges from 250 to 400 RE; for males aged 10 -12 years it ranges from 300 – 500 RE and 300 – 600 RE for those aged 12 years and above. For females aged 10 years and above, the RDA ranges from 270 – 500 RE (Olson, 1996). Therefore the average of the upper safe limits was found to be 500 RE (1, 665 IU). However, bearing in mind that in this study, fortification was being done at 20% of this RDA value (333 IU or 100 RE); no threats of toxicity were posed to the target population. Additionally, according to Trumbo *et al* (2001), the upper toxicity limits per day were set for children as 900 RE (3,000 IU) for the 4 -8 year olds; 1700 RE (5,661 IU) for the 9-13 year olds and 2800 RE (9,324 IU) for the 14 – 18 year olds, respectively.

The 20% RDA level (corresponding to 333 IU) of fortification was selected in line with fortification guidelines; a food is fortified at between 15 and 20% RDA, with the assumption that the target population will obtain the rest of the nutrient's RDA from other food sources consumed (MI, 2008).

The level of 832.5 IU vitamin A (corresponding to 50% RDA) had been considered for possible use in therapeutic feeding situations. However, the study sought to develop a product that could be used on a daily basis by the target population, without causing toxicity for the management of mild to moderate VAD and for the prevention of the onset of the same. Thus, the product formulation that was produced on a large scale for use in the study was that fortified at 20% RDA (333 IU).

5.2.3 The biochemical quality of the fresh vitamin A fortified mango nectar

The results of the biochemical analysis of the freshly prepared mango nectar were as expected for similar products (see Table 4) and corresponded with those found by other researchers (Alaka *et al.*, 2003; Falade *et al.*, 2004). The reduction in the quantity of vitamin A during processing confirmed the adequacy and accuracy of using the 40% overage.

5.2.4 Microbiological quality of the fresh fortified mango nectar

The quantities of the preservative and citric acid used together with the pasteurization regimes employed gave a product which was microbiologically stable with no observed presence of coliforms, yeasts, moulds or other bacteria. This was consistent with results found by Hashmi *et al.* (2007).

5.3 Sensory evaluation of the fresh fortified mango nectar by a trained sensory evaluation panel

5.3.1 Recruitment and training of the sensory evaluation panel

The probability of correctly identifying the odd sample was p=1/3 (since only 1 sample of the 3 was odd; there was a 1 out of 3 chance that the correct (different) sample would be picked just by chance (guessing), assuming that the judges had no ability to detect the differences then this would have been the probability (0.33). However, 18/20 panelists correctly identified the odd sample, and this gave a probability of p=0.9.

From the results of this study, the power of almost 1 at p=0.9 indicated that there was no failure (among the 18 panelists) to detect an existing difference. It confirmed that there were no significant inter-panelist differences and therefore all the 18 panelists had an equally good ability to detect the differences among the samples. Although the first 10 panelists were selected, any of the 18 would have been equally effective as a panelist. Repeated screening tests achieved similar results and confirmed this. This gave an assurance of the results of the sensory evaluation of the developed product by this panel.

5.3.2 Sensory evaluation of the developed fortified mango nectar

Four attributes (colour, taste, mouthfeel and overall acceptability) represented the developed fortified mango nectar's sensory profile. The product was scored highly for all these attributes, confirming that it was highly acceptable to the panelists (see Table 6).

5.4 The Storage Stability of fortified Mango Nectar

Stability of fruit juices during storage is determined by nature of packaging, storage temperature, length of storage period, presence or absence of light, presence or absence of oxygen, relative humidity, adequacy of pasteurization and absence or presence of preservatives (Hashmi *et al.*, 2007; Rodriguez-Amaya, 1997; Vasquez-Caicedo *et al.*, 2007; Kabasakalis *et al.*, 2000.) These conditions in turn influence the various quality attributes of the stored fruit juice. Additionally, addition of pectin or use of pectinase enzymes also plays a role in stability of the product regarding separation of the components or 'settling'. If 'clear' or 'clarified' juices are desired then pectinase enzymes are used while if 'cloudy' juices are required then pectin or stabilizers may be added (Bates *et al.*, 2001). In this study neither pectinase enzyme nor stabilizers were used since a 'natural' product was desired. The storage temperatures used in the study (4°C, 25°C, and 38°C) represent all the conditions available in Kenya in the distribution channel and at home. The choice of these storage temperatures was therefore practical.

5.4.1 Changes in the biochemical properties of the fortified mango nectar during storage

5.4.1.1 Ascorbic acid

The decrease in ascorbic acid content was expected and consistent with results of other researchers for similar products, whereby it has been found that loss of ascorbic acid is considerably affected by storage time and temperature (Kabasakalis *et al.*, 2000).

Vitamin C (ascorbic acid) is an important component and nutrient in most fruit juices, contributing to nutritional quality and stability of the product through its antioxidant properties (Kabasakalis *et al.*, 2000, Falade *et al.*, 2004). It also contributes to the stability of beta-carotene – another important nutrient – in fruit juices, valued for its contribution to attractive fruit juice colour and its provitamin A nutrient. Therefore, loss of ascorbic acid has been regarded as one of the most important causes of quality and colour changes in fruit juices during both processing and storage (Alaka *et al.*, 2003; Falade *et al.*, 2004).

5.4.1.2 Titratable acidity and pH

The decrease in titratable acidity and pH during storage were as expected and consistent with results of other researchers for similar products (Alaka *et al.*, 2003; Falade *et al.*, 2004) (see results in Tables 5 and 6).

5.4.1.3 Soluble solids content (°Brix)

The changes in the soluble solids content were as expected and consistent with results of other researchers for similar products (Alaka *et al.*, 2003; Falade *et al.*, 2004).

5.4.2 Changes in vitamin A content of the fortified mango nectar during storage

Although vitamin A is relatively unstable under normal storage conditions, particularly in harsh environments, the form of vitamin A fortificant that was used – Dry Vitamin A Acetate, Type 325 CWS/F – was relatively stable.

At the beginning of the storage period, the product contained 333 IUs (100 RE) of vitamin A. At 4°C, this value remained unchanged throughout the storage period suggesting that this is the best storage temperature of the fortified mango nectar; as the product continued to supply the desired amount of the nutrient (100 RE or 20% RDA) throughout. At 25°C and 38°C, there was a loss of 21.5 % and 28%, respectively, over the five-week storage period. Thus, the product stored at 25°C supplied 15.7% of the RDA (78.5 RE), while that stored at 38°C supplied 13.4 % of the RDA (72 RE). This suggests that for the product samples that will be stored at 25°C and 38°C, the overage should be increased to 61.5% and 68%, respectively; for a five-week shelf-life period. At these increased overages the products would pose no danger of toxicity to the consumers since the products would be supplying just 24.3% RDA and 25.6% RDA, respectively. This is adequate since the product is considered a fast moving commodity; and it is envisaged that it would be consumed daily by the target population, though it is not a medicine. However, for a longer shelf-life, these overages may be combined with use of opaque packaging such as tetrabrik® which will preserve the nutrient by protecting against UV light. The use of tetrabrik® packaging has a cost implication since the packaging is expensive and would require to be undertaken on scale up, at industrial level; where the economies of scale would reduce the effect somewhat. Alternatively, increasing the amount of ascorbic acid in the product through fortification may be considered, since ascorbic acid has demonstrated antioxidative properties and would contribute to conserving the vitamin A in the product (Kabasakalis *et al.*, 2000).

5.4.3 Changes in beta-carotene content of the fortified mango nectar during storage

Mango is a rich source of beta-carotene and preliminary analysis of the Ngowe mango pulp used confirmed that its beta-carotene content was 5.90 µg/ml. However, after processing this was found to be 0.95 µg/ml. During storage this was further reduced, with retention being 78.5% and 67%, at 25°C and 38°C, respectively, at the end of five weeks. The losses in beta-carotene content most likely occurred due to both enzymatic and non-enzymatic reactions; and were associated with losses in ascorbic acid in the product. The rate of loss of ascorbic acid has been found to increase with storage time and temperature In processed fruit juices, non-enzymatic browning occurs through the Maillard reaction and leads to formation of end products such as furans, furanones, ketones, pyranones and pyrroles – which contribute to both off-colour and off-flavour in fruit juices (Khan and Robison, 1993; Falade *et al.*, 2004; Hashmi *et al.*, 2007).

Beta-carotene is highly unstable, with instability increasing under condition of low pH (below pH 5), heat, high oxygen and light (Vasquez- Caicedo *et al.*, 2007). Though a compromise was reached in the formulation of the product to have a pH of 5 (greater than the pH 3.5 in most fruit juices), still there was a loss in the beta-carotene content of the product. Although the product was de-aerated by hot-filling, not all the oxygen was expelled and some could have dissolved and promoted the beta-carotene degradation (Vasquez- Caicedo *et al.*, 2007). Additionally, since the packaging of the product was clear and the product was not protected from light during storage to simulate the usual distribution conditions – it also lost its bright yellow colour at the higher storage temperatures and this was later followed by the development of a brown colour. No losses in either ascorbic acid or beta-carotene were recorded at 4°C; suggesting that refrigeration temperatures promote stability of the nutrients.

5.4.4 Changes in microbiological quality of the fortified mango nectar during storage

A microbiologically stable product was developed (see Table 5). This confirms that good manufacturing practices were used and that the pasteurization regimes and amount of preservative used were adequate to ensure that no microbes present survived, consistent with previous research (Falade *et al.* 2004).

5.4.5 Changes in the sensory properties of fortified mango nectar during storage

At $P<0.05$, there was a significant difference in the colour, taste, overall acceptability of the product stored at 25°C and 38°C (S2 and S3), during the storage period, as scored by the judges, see results in Table 7. There was no significant difference in the same quality attributes of the sample stored at 4°C at the same level. For the samples stored at 25°C, the changes in the sensory qualities, especially taste, were not critical. For the samples stored at 38°C, these changes, especially taste and colour were critical after the second week and the product was no longer acceptable.

5.5 Consumer acceptability evaluation

The school composition by age also included pupils who were older than 15 years (see Table 8). This was expected since with the initiation of the government's free primary education programme, primary school education was opened up for anyone of any age who wished to participate. Previously and under ideal conditions, the oldest age recorded would have been 15 years.

Majority (98.5%) of the pupils liked the fortified mango nectar very much and confirmed that they would buy it or would ask their parents to buy it for them (see Tables 9 and 10). The high scores for colour, taste and overall acceptability supported this. Overall the scores seemed similar between the boys and the girls; there was no significant difference between the scores at $P<0.05$. In comparison to other soft drinks sold within and around the school compound, and in supermarkets, the developed product was found to be a good buy (at KSh 21.00 – 25.00). Majority of the soft drinks manufactured and sold in Kenya have recently come under attack for luring unsuspecting customers with mouth-watering pictures of fresh fruit on the labels, while the drinks are only imitations of the flavour, colour and aroma of the fruit that appears on the package (Olielo, 2009; Wahome, 2009).

Analysts confirm that the abundance of synthetic drinks in Kenya is caused by the high cost of manufacturing natural fruit juices. The lack of strong consumer protection and the declining levels of disposable income among consumers make them more vulnerable to manufacturers of much cheaper imitations (Wahome, 2009).

The fortified product was successful among the sampled target population because it met the requirements of new fruit juice products targeted at children. Important considerations among children (and their parents) when deciding whether or not to accept new juice products are: colour, taste/flavour, price, nutrition, convenience and packaging (Frank 2000; Hazen 2007). In beverages, children like bright colours, good taste that is not too sweet, fruity flavours, and packaging that is easy-to-open, and easy-to-drink from (Frank 2000; Hazen 2007). Ideally, the package should be single-serve and of convenient size and shape. Children like products that they can afford with their pocket money. Products that promote health and wellness appeal to parents, who are increasingly becoming aware and concerned about the contribution of flavored drinks to their children's obesity. It is envisaged that like in the US, fortified fruit juice products will gain ground in Kenya.

Mango is one of the most popular tropical fruits and processing it into a nectar provides a convenient and attractive way of presenting it for consumption among the target population. Additionally, using it as a vehicle for the vitamin A fortificant works well since it does not involve any change in dietary behaviour – this is a key factor in the acceptability and adoption of any new fortified food (ILSI/FAO, 1997). Thus it constitutes a good food-based strategy for alleviation of micronutrient malnutrition, especially VAD.

5.6 Cost of the product

In seeking the best formulation of the product, the cost of each of the formulations was determined. Considering only the cost of pulp and other ingredients, it was found that the cost of other ingredients (sugar, citric acid and preservative) remained constant, the cost of pulp increased depending on the percentage used in the formulation. At 25% pulp, the cost of formulation was KSh 3,270; at 37.5% it was KSh 4,520 while at 50% it was KSh 5,770. It can be seen that as the amount of pulp increased, so did the cost of the formulation and ultimately the cost of the product. For a 100-litre batch of product the cost of other ingredients was constant at KSh 770 (with optimal quantities of these other ingredients); therefore to determine the cost of the formulation (at any point between 25% and 50% pulp) this expression was derived:

$$y = 100p + 770$$

Where y = cost of 100 litres of product in KSh

p=cost of mango pulp in KSh

but p = (x%*100)

where x% = percentage of mango pulp in product

therefore p = x%* 100; 100 is the cost of 1 litre of mango pulp

Substituting x% with 25%, 37.5% and 50% in the above expression gives values that correspond with those given above (KSh 3,270, KSh 4,520 and KSh 5,770, respectively).

Assumptions made in costing the product were:

a. Cost of energy included cost of refrigeration;
b. Cost of utilities included cost of water
c. Water was not costed as an ingredient but together with other costs (utilities)

d. Cost of running equipment was costed together with other costs; it was assumed that there was already an existing plant in place with equipment (for a start up enterprise, then this would have to be costed)

e. Technical expertise and supervision were not costed (were supplied by the researcher and supervisors)

f. Laboratory analyses were not costed

The total cost of developing a 100-litre batch of the best product was found to be KSh 8,461.60 – the cost of supplying 400 children with 20% RDA of vitamin A per day. The cost per child was found to be KSh 21.20. The cost of fortificant used was KSh 2.40 for 100 litres of product – working out to just 0.03% of the cost of the product (and less than 1 Kenyan cent per child). The form of fortificant used – Dry Vitamin A Acetate, Type 325 CWS/F – is highly concentrated; containing 325, 000 IU Vitamin A per gramme, and cost € 46.58 per kilogram (approximately KSh 4,751.16, at the time of study; exchange rate of KSh 90.00 for € 1).

At the proposed increased overages to counter the losses at 25 °C (61.5%) and 38 °C (68%), the incremental cost of the product is negligible. At an overage of 61.5% the cost of fortificant is KSh 2.80 for a 100-litre batch of product and represents an increase of only 40 Kenyan cents. Likewise, for the same amount of product, an overage of 68% increases the cost of fortificant to KSh 2.88 and represents an increase of 48 Kenyan cents. Therefore at 61.5% and 68% overages, the overall cost of the product increases to KSh 8462.00 and KSh 8462.08, respectively – representing increases of 0.005% and 0.006%, respectively.

This confirms that food fortification is a highly cost-effective way of supplying essential micronutrients such as Vitamin A to the vulnerable populations. Compared to other products on the market consumed by the school children, the developed product was found to be a relatively cost effective way of supplying nutrients to this target population. Even for a family pack of 1 litre (at KSh 90.00), the developed product would still cost less than most market brands in the 'healthy drink' segments whose prices ranged from KSh 105 to KSh 135 (prices as at time of study).

5.7 Potential of the vitamin A fortified mango nectar as an intervention in the alleviation of VAD among primary school children in Kenya

Primary school children represent an important age group directly impacted upon by the MDGs of achieving universal primary education and reducing child mortality, especially. Additionally, interventions such as vitamin A capsule supplementation, mainly target the under 5's. In many ways this is the 'forgotten' or 'ignored' age group. Given that the meals provided in the school-feeding programme were low in animal-source vitamin A, and most of the children came from low-income households, it is likely that the pupils were not receiving adequate dietary vitamin A neither at school nor at home. At the fortification levels used, the product poses no danger of toxicity to any of the children within that age group. Therefore, this product holds promise in improving the school pupils' vitamin A status.

The amount added will be significant as performance of children is expected to improve they will have better health and miss school less often and their cognitive abilities will also improve and so their overall performance in school will be enhanced. The product supplied at least 20% of the RDA for the given age group (males 10-12 years and females less than 10 years); however, overall impact of the product's consumption will depend on the amount consumed and the frequency.

The production of vitamin A fortified mango nectar has potential of being scaled up into a micronutrient programme. In recent times, micronutrient programmes are gaining ground in their potential to achieve the MDGs in a quick and cost-effective way – offering a "short route" (MI, 2007). It is suggested by The World Bank that micronutrient programmes are crucial in the achievement of goals for reducing child mortality, improving maternal health and child development, promoting gender equality, eradicating extreme poverty and hunger, achieving universal primary education, and combating HIV/AIDS, malaria and other diseases (MI, 2007).

Over the years, analyses of food fortification programmes have found that the cost of fortificant comprises about 90% of the total costs, depending on the concentration of the nutrient in the fortificant. This is a significant proportion and constraint in uptake and upscale of food fortification programmes (Sanghvi *et al.*, 2007). In the present study, the cost of fortificant was found to be just 0.03% of the cost of the product; because of the highly concentrated nature of the fortificant used – 1 gram contained 325,000 IUs of vitamin A. This was important in reducing both total and unit cost of the product. The findings from the study indicate that there is potential and opportunity for industrial scale up of production of fortified mango nectar for use by primary school children in Kenya. It would cost just KSh 21,043.00 (US $ 292.30) to supply 1 public primary school (974 pupils, like Loresho Primary School) in a low-income area with 20% of their vitamin A RDA for one day. For a school term of 13 weeks, this cost would be KSh 1.37 million (US $ 18,997).

This calls for strong public-private partnership with both local and international organizations to devise programmes into which this fortified product can be incorporated, such as the revival of school feeding programmes with international development partners and government pitching in to support industrial production of the product.

Three options may be explored for scaling up production:

a. Depending on their scale of operations, the larger industries could be provided with the fortificant at no cost and produce the fortified mango nectar as a social good or as part of their corporate social responsibility
b. Governments could exempt the vitamin A fortificant from import and related taxes, to make it more affordable and the industries could manufacture the fortified drink, add a modest mark-up and have the product bought by international agencies involved in VAD alleviation efforts
c. Industries could produce the product under contract, whereby it would be bought by all those involved in VAD alleviation efforts

Additionally, for enhanced effectiveness, this food fortification initiative must be supported by adequate food regulations and labeling, quality assurance and monitoring to ensure shelf life and adequate levels of micronutrients, public education, and compliance (Bégin *et al.*, 2001).

5.8 Challenges

During this study a few challenges were experienced and they included:

a. Lack of technical information on a similar product

b. High cost of vitamin A analysis

c. Lack of time

d. Difficulty in conducting a consumer acceptability survey with young children (especially the under-8's) and the relatively poor literacy among the pupils (especially those under 10) in the targeted school. This was because the pupils were found not to have properly mastered the basics in reading and writing before moving to the next class or grade. With the opening up of primary schools under the FPE program, pupils can just progress to the next class or be admitted to a class appropriate for their age, even without the proper grounding. Also, teachers are overwhelmed (teaching up to 70 pupils in one class) and cannot ensure that weak pupils get the proper foundation in the earlier years, especially in reading and writing. Explaining the purpose of the survey therefore took more time and also some of the pupils had to be helped to fill in the forms properly.

CHAPTER SIX CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

In response to the current high level of vitamin A deficiency among school going children and lack of suitable vitamin A food supplements, this study attempted to develop a suitable intervention product – the fortified mango nectar, which is rich in vitamin A.

It was observed that the sources of vitamin A available to the primary school children in the identified study area were found to be mainly from plant source foods, and inferred to be inadequate in supplying the required vitamin A RDA to the pupils.

It was possible to develop a low cost, stable, and highly acceptable intervention product – vitamin A fortified mango nectar – using locally available resources and technologies. The drink is not a prescription drink; it can provide at least 20% of the vitamin A RDA for the target age group and improve their well-being and ultimately boost their school performance.

The project and product represent new business opportunities for both new and existing enterprises to scale up production. The product may be incorporated into school feeding programmes, with adequate advocacy and social marketing. This product and technology represent an opportunity for technology transfer: the community can be shown how to process the product at-home, or at community level (in small-scale processing firms) provided the fortificant can be made available in a form that lends itself well to this. However, care needs to be taken with Vitamin A since the packaging would need to adequately protect the Vitamin A from light, oxygen and heat and should be in convenient quantities for various quantities of mango nectar (Bégin *et al.*, 2001).

The product can be accessed from the market by many, once it is developed. It is therefore a product that has the potential of being used to alleviate VAD.

6.2 Recommendations

Based on the findings of this study, we suggest the following strategies aimed at improving the availability of affordable, acceptable and stable vitamin A food supplements- such as the vitamin A fortified mango nectar.

It is necessary to optimize the product formulation for taste, colour and acceptability; nutrient delivery and cost. Similarly, to maintain product stability during distribution and at home or point-of-consumption storage, the product should be stored away from light; preferably at 4°C (ideal) or 25°C (if refrigeration is not available). Also to be considered is increasing the overage of fortificant to 61.5% and 68%, for the fortified product that will be in distribution chains of 25°C and 38°C respectively, based on results of this study to ensure that the product delivers, at least 20% of RDA after at least 5 weeks in the distribution chain.

To determine the potential of the product in improving the vitamin A status of primary school children, bio-efficacy study should be conducted among the school children. Also, advocacy and social marketing should be undertaken to increase demand for the product among the target population (and parents) and to get the local beverage manufacturing

industries and the government on board to scale up the production of the fortified mango nectar.

Finally, potential for at-home fortification should be explored through public nutrition education and technology transfer.

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APPENDICES

APPENDIX 1 Key Informant Interview Schedule

1. Do you have a school-feeding programme in place?
2. Is it open to all the pupils in the school?
3. Do the pupils pay for the meals? If yes, how much?
4. What foods are included in the menu?
5. What are children's favourite meals?
6. Do you buy all the food used or is some of it grown in the school garden? Which food stuffs are bought and which are grown in the school garden?
7. Are there any limitations to providing food to the pupils? If yes, which ones?
8. What beverages are consumed by the pupils and where do they come from? How much do they cost? What do you think of their nutritional value?
9. Do you think the fortified mango drink will fit into the school-feeding programme?
10. What are the socio-economic backgrounds of the children in this school?

APPENDIX 2 SENSORY EVALUATION QUESTIONNAIRE 1
TRIANGLE TEST (FOR TRAINING OF PANELLISTS)

Date________________ Name________________ Product________________

Instructions: Here are three samples for evaluation. Two of these samples are duplicates.

Separate the odd sample for difference only.

Sample	**Tick the odd sample**
______	______________
______	______________
______	______________

Indicate the degree of difference between the duplicate samples and the odd sample.

Slight ______________ Much ______________

Moderate ______________ Extreme ______________

Acceptability:

Odd sample more acceptable ______________________

Duplicate sample more acceptable ____________________

Comments:

APPENDIX 3 SENSORY EVALUATION QUESTIONNAIRE 2

SENSORY ANALYSIS BY UNIVERSITY OF NAIROBI PANELLISTS

Name________________________________ Date______________

Instructions

You have been given, in random order, coded samples of mango nectar. Please evaluate them for colour, taste, mouth feel and overall acceptability, using the intensity scale given below. Rinse your mouth with water after examining each sample.

1=dislike very much 4=neither like or dislike 7=like very much

2=dislike moderately 5=like slightly

3=dislike slightly 6=like moderately

Sample	Colour	Taste	Mouth feel	Overall acceptability

Do you like the product? Yes/No ______________

Comments:

APPENDIX 4 TRAINING SHEDULE OF ENUMERATOR

Subject matter	Teaching method	Teaching aids	Day
Study title, objectives, aim and purpose Questionnaire contents; coding and questions	Lecture Discussion	Chalk board and chalk Notes	1
Sensory evaluation: sample preparation and presentation to consumer panelists and recording of scores	Lecture Demonstration Role play	Product samples Copies of sensory evaluation questionnaires	2
Interviewing skills and questionnaire administration: asking of questions, probing, clarification of answers, recording responses	Role play Question and answer session Discussion	Copies of the questionnaire Flip chart and markers	3

Creating rapport with respondents	Role play		
Ethics in field work, consent and confidentiality Training evaluation	Discussion Role play Question and answer session	Flip chart and markers	4

APPENDIX 5TABLE OF RANDOM NUMBERS

19614 62349 42831 95113 95836 22530 61885 50796 24028 03405 58697 31973 81638 36566 08312 27886 57696 25592 23798 55425

74088 65564 43511 42082 91785 80210 96823 82002 01178 06316 06301 94202 42709 31717 82321 28666 91221 95386 32454 14611

16379 19711 13140 34733 34361 52228 07973 52925 81916 40170 62287 56164 59943 12027 72998 22514 15857 84645 99605 39981

39151 69459 68076 18292 33869 94132 75467 86011 53665 87202 79157 98375 46547 61303 51054 22940 89659 80535 74691 40836

17986 24517 69186 80468 83868 61672 98072 91942 88638 47121 24558 99241 46699 76243 31842 54245 93233 82798 10812 38563

14595 35050 80583 70361 65358 70469 48917 48129 86558 84750 18449 46418 46574 79630 11071 44430 08074 89810 85806 57995

40469 27478 41047 26792 87119 89509 48624 18248 43994 01760 91579 01907 10312 89543 94664 91294 48521 90740 68222 39055

44526 67331 78466 03395 72176 18103 91465 51898 96205 27933 72146 05764 79010 23428 35163 05494 02687 83117 41890 36956

93365 54526 17635 09697 55169 79954 61220 18721 45416 71964 22400 91490 29541 12501 32882 23904 74920 25954 84861 63624

22356 93208 82447 31405 72002 20582 67387 66575 32261 30781 49833 09258 89422 87474 41340 61185 99629 78978 04961 33439

10734 71571 00209 90401 72249 04037 88178 84299 78545 49201 62134 87244 11873 57196 82509 11842 20138 51721 99719 36036

83722 79712 99457 72570 36192 40221 12193 03785 04329 14182 73548 80114 32209 67663 86963 50307 01518 40699 74274 53901

25775 65178 42194 19043 14918 53417 49314 39761 10971 90472 78490 61715 07990 12288 07510 32545 20849 04710 34643 05157

07761 82928 24330 14939 60571 10995 99132 28775 44682 39304 31010 66075 59245 83618 90717 46856 18989 91322 89500 57514

31131 30196 09865 45906 55006 10694 45276 91816 19819 55799 28652 36166 23642 61715 86079 13769 56057 58573 93977 42403

64628 89126 05309 20830 41693 10581 77800 25734 18969 64623 72749 13347 13862 72778 07426 67341 00190 27157 95970 81452

91254 24090 01911 60767 93050 48734 09801 92087 82780 35686 65030 26128 09949 23096 80314 58910 83208 79446 48871 00784

25752 03091 55248 79251 34652 41577 02955 12872 30941 14622 49067 27904 01791 19472 93948 85218 92987 61357 58347 40269

39111 73146 12317 84120 04631 49184 89848 48579 04126 25492 49953 74674 14634 31690 69444 09370 38752 55424 11800 43395

06089 15630 77772 50103 39295 81776 06028 13827 95452 63937 94617 13317 36602 62943 58194 28207 94518 45205 28249 38241

APPENDIX 6DSM DRY VITAMIN A ACETATE PRODUCT SPECIFICATION SHEET

DSM Nutritional Products DSM

Product Data Sheet

Dry Vitamin A Acetate, Type 325 CWS/F

Description

Dry Vitamin A Acetate, Type 325 CWS/F consists of light yellow, free-flowing particles (beadlets). They contain 325 000 IU vitamin A (97 500 µg retinol) per gram. The individual particles contain an oily solution of vitamin A acetate finely dispersed in a cornstarch-coated matrix of gelatin* and sucrose. dl-α-tocopherol is added as an antioxidant.

*Gelatin obtained from fish skins of food fish processed for human consumption

Product Identification

Product code: 04 3630 5

Chemical name: all-trans-3,7-dimethyl-9-(2,6,6-trimethyl-1-cyclohexen-1-yl)-2,4,6,8-nonatetraene-1-yl acetate

Synonyms: retinyl acetate, all-trans vitamin A acetate, vitamin A acetate

CAS No.: 127-47-9

EINECS No.: 204-844-2

Empirical formula: $C_{22}H_{32}O_2$

Molecular mass: [illegible].54 g/mol

Specifications

Appearance: light yellow, free flowing particles

Identity for vitamin A acetate: corresponds

Identity for tocopherol: corresponds

Fineness (US standard sieves)
100 % through sieve No. 20
min. 90% through sieve No. 40
max. 15% through sieve No. 100

Dispersibility in water: satisfactory

Loss on drying: max. 6%

Vitamin A content (HPLC): min. 325 000 IU/g

Microbiological quality: corresponds

Dispersibility

Dry Vitamin A Acetate, Type 325 CWS/F disperses quickly and completely in cold water, fruit juices, milk and other liquids.

High concentrations may give cloudy dispersions which, however, remain uniform for relatively long periods.

APPENDIX 7SENSORY EVALUATION QUESTIONNAIRE 3
SCHOOL-BASED CONSUMER SENSORY ANALYSIS

Name____
School____
Date____

Instructions

Each pupil should be introduced to the product by explaining to him/her what the mango nectar is made of. Allow them to examine and taste the products randomly and freely. They should rinse their mouths after examining each sample. Then assist the pupils to fill the product scores in table below using the given scale:

1=dislike very much
2=dislike moderately
3=dislike slightly
4=neither like or dislike
5=like slightly
6=like moderately
7=like very much

Sample	Colour	Taste	Mouth feel	Overall acceptability

Also, assist the pupils to respond to these questions:
Do you like the product? Yes/No ________________

Would you buy the product or ask your parents to buy the product for you?
Yes/No ________________

Any other comments

____

Please thank the pupil after the exercise

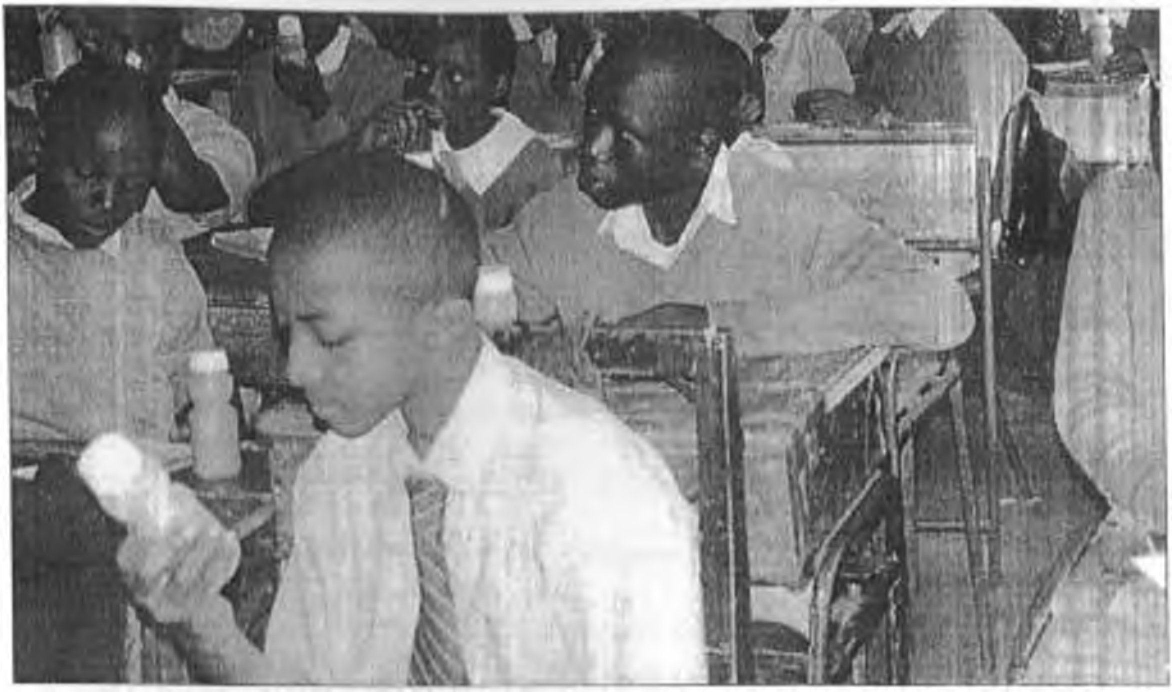

Figure 10 : This photo shows pupils (the end-users) examining the final product before scoring it for aspects of colour and attractiveness of the package.

Figure 11: The fortified mango nectar fortified was received with a lot of enthusiasm among its target population.

Foods bought by the pupils around the school

Among these snacks and drinks were: potato crisps and chips, *mdazi* (a type of Kenyan doughnut), *samosa* (triangular deep fried meat pie), an assortment of sweets, buns, cakes and various soft drinks. The soft drinks identified on sale in and around the school were mainly commercially produced ready-to-drink juices (RTDs) as well as sodas (carbonated soft drinks) and they cost between KSh 15 – 25; depending on the type and manufacturer. None of them were fortified and only one contained real fruit. Those that were similar to the developed mango nectar, in that they were considered healthy and having added benefits were sold mainly in the supermarkets. Some of these products had label claims of being enriched with vitamins A, C, or E (either individually or in combination) but the amounts were not always explicitly listed on the product labels. Table 2 shows the results of the drinks survey.

Cost of the fortified mango nectar

The cost categories of the product included ingredients, fortificant, packaging, other costs (labour, and energy). The ingredients included: mango pulp, sugar, citric acid and potassium metabisulphite. As shown in section 4.2, three different formulations and four different packaging types were considered. The best fortification level was found to be at 20 % RDA (333 IU retinol) with a 40% overage. The cost of fortifying a 100-litre batch of product was found to be KSh 2.70. The costs of each of the different formulations are given below (Tables 10 – 12).

Table 11: Cost of first fortified mango nectar formulation (for 100-litre batch)

Cost category	Percent in product (%)	Amount/Quantity	Unit cost (KSh)	Total Cost (in KSh)
Ingredients				
Mango pulp	25	25 litres	100.00	2,500.00
Sugar	10	10 kg	50.00	500.00
Citric acid	0.5	0.5 kg	300.00	150.00
Potassium metabisulphite	0.2	0.2 kg	600.00	120.00
Vitamin A	0.000574	0.574g	4,192.20	2.40
Packaging		400	4.80	1,920.00
Sub-total cost				**5,192.40**
Other costs – labour, energy, utilities (10% of sub-total costs)				519.20
Total cost				**5,711.60**

Note: Prices were inclusive of VAT (at 16%), where applicable.
Cost of energy included cost of refrigeration; cost of utilities included cost of water

Table 12: Cost of second fortified mango nectar formulation (for 100-litre batch)

Cost category	Percent in product (%)	Amount/Quantity	Unit cost (KSh)	Total Cost (in KSh)
Ingredients				
Mango pulp	37.5	37.5 litres	100.00	3,750.00
Sugar	10	10 kg	50.00	500.00
Citric acid	0.5	0.5 kg	300.00	150.00
Potassium metabisulphite	0.2	0.2 kg	600.00	120.00
Vitamin A	0.000574	0.574g	4,192.20	2.40
Packaging		400	4.80	1,920.00
Sub-total costs				**6,442.40**
Other costs – labour, energy, utilities (10% of sub-total costs)				644.20
Total costs				**7,086.60**

Note: Prices were inclusive of VAT (at 16%), where applicable. Cost of energy included cost of refrigeration; cost of utilities included cost of water

Table 13: Cost of third (best) fortified mango nectar formulation (for 100-litre batch)

Cost category	Percent in product (%)	Amount/Quantity	Unit cost (KSh)	Total Cost (in KSh)
Ingredients				
Mango pulp	50	50 litres	100.00	5,000.00
Sugar	10	10 kg	50.00	500.00
Citric acid	0.5	0.5 kg	300.00	150.00
Potassium metabisulphite	0.2	0.2 kg	600.00	120.00
Vitamin A	0.000574	0.574g	4,192.20	2.40
Packaging		400	4.80	1,920.00
Sub-total costs				**7,692.40**
Other costs labour, energy, utilities (10% of sub-total costs)				769.20
Total costs				**8,461.60**

Note: Prices were inclusive of VAT (at 16%), where applicable. Cost of energy included cost of refrigeration; cost of utilities included cost of water

With the best formulation; the cost of vitamin A fortificant was just 0.03% of the product cost. The cost of a 100-litre batch of the best product was found to be KSh 8461.60. The cost of one 250-ml bottle of the fortified mango nectar; i.e. the cost of supplying one child with 20% RDA of vitamin A was found to be KSh 21.20.