

THE EFFECTIVENESS OF MICRONUTRIENT FORTIFICATION OF MAIZE MEAL IN IMPROVING THE NUTRITIONAL STATUS OF CHILDREN

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vir Christelike Hoër Onderwys

**This thesis is in memory of my father:
with love and gratitude**

Dedicated to my loving and supportive family – my wife, Tshisikhawe
and daughter, Phathutshedzo, mother, brother and my in laws

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CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

Preventable and controllable disorders resulting from insufficient dietary intake of essential micronutrients such as vitamin A, iron and iodine have unacceptably high prevalences in developing countries. Physical deformities, blindness, reduced work and intellectual capacity, increased morbidity and mortality associated with certain infections, severe anaemia, as well as developmental delays and attention deficits, are some of the manifestations of micronutrient malnutrition, causing needless suffering and loss of millions of lives throughout the world (Maberly, 1994).

Only a few national studies on nutritional status of the South African population are available. However, several isolated studies have indicated the presence of micronutrient deficiencies, especially in young children below the age of 5 years (Vorster *et al.*, 1997).

The South African Nutrition Survey Group (SANSS) conducted a meta-analysis of dietary surveys undertaken in South Africa for twenty years prior to 1996. The data was presented as mean intakes of energy, macronutrients and micronutrients for all ages and population groups. The findings indicated poor intakes of micronutrients such as vitamin A, C, B6, thiamin, riboflavin, niacin, iron zinc and copper amongst Africans (Voster *et al.*, 1997).

The only national study on preschool children, in which biochemical variables were measured, was done by the South African vitamin A Consultative group (SAVACG). Anthropometric, vitamin A and iron status of children aged 6 to 71 months were assessed. Thirty three percent of the children were found to have marginal vitamin A deficiency and 21.1% were found to be anaemic. Iron deficiency was found in 12.1% of urban children as compared to 8.3% of rural children. Stunting was found in 22.9% of children with the highest prevalence amongst those residing in rural and informal housing areas. Based

on these findings, it can be estimated that 1 520 000 preschool children are undernourished due to chronic undernutrition (SAVACG, 1995).

Recently, similar results to those of the SAVACG study were found through the National Food Consumption Survey (Labadarios *et al.*, 2000). The results of the survey indicated that 22 % of South African children aged 1 – 9 years were stunted, 9 % were underweight and 3 % were wasted (Labadarios *et al.*, 2000). In terms of micronutrient intake, 55 – 68% of the children had vitamin A intake that was only 50% of the recommended level. A higher percentage (62 – 73%) of rural children exhibited an intake of vitamin A below 50% of their Recommended Dietary Allowances (RDA) as compared to urban children (48 – 62 %). Iron intakes were found to be consistently low for all age groups in all provinces. Nationally, 41 – 63% of children consumed less than 50% of RDA. The same was found for zinc and vitamin E. Generally, the survey showed that a great majority of children consumed diets deficient in energy and of poor nutrient density to meet the requirements for most micronutrients.

Waterlow (1994) indicated that in cases where there is severe stunting and wasting, there is a definite need for nutritional intervention. Pelletier (1994) also confirmed that dietary intervention can reduce morbidity and mortality rates amongst children.

These findings prompted the South African government to place improvement of nutritional status as one of its priorities. This led to the establishment of the Directorate of Nutrition within the National Department of Health in 1995. The directorate hosted a workshop in 2000 with the aim of seeking consensus on several issues related to fortification. It was recommended after the workshop that vitamins A, B6, folate, niacin, riboflavin, thiamine and calcium could be safely included in the fortification programme. There are several options in which the problem of under-nutrition amongst children can be addressed. Fortification of a staple food is one of the proven and most cost-effective methods of addressing under-nutrition in children (Romano *et al.* 1995). Since the most affected population group in South Africa is African, it

is therefore logical that maize meal would be a food vehicle of choice for any fortification targeting the African population. There is, however, no scientific data available on the effectiveness of maize as a vehicle of vitamin fortification.

This study will, therefore, assess the effectiveness of maize meal fortified with vitamin A, folic acid, thiamine and riboflavin in improving the anthropometric and biochemical nutritional status of children aged one to three years residing in Oukasie, North West Province.

1.2 MOTIVATION FOR THE STUDY

Though fortification is an old concept, South Africa has not truly implemented a well-directed National Fortification programme, except for the fortification of table salt with iodine (Jooste *et al.*, 1995). There is very little data available on the outcomes of fortification in South Africa. One of the very few is the fortification of curry powder with iron, targeted to the Indian population of Kwazulu – Natal (Ballot *et al.*, 1989). This study was done on adults and the results cannot be extrapolated to children. Van Stuijvenberg *et al.* (1999) also found positive results by fortifying biscuits with iron. The vehicle used in both studies was not a staple; this study will therefore be the first to assess the effectiveness of a staple as a vehicle for food fortification.

Maize is the vehicle of choice for fortification of the national government and it is therefore important that its effectiveness should be assessed. From the National Food Consumption Survey, thirty two percent of the respondents suggested that maize meal is the ideal choice of food to be fortified; a distant second was bread with 10% (Labadarios *et al.*, 2000). This also means that maize is a vehicle of choice by the community at large.

Maize is a widely consumed staple in Southern Africa and it is therefore important that the outcomes of the study will not only benefit South Africa, but the major part of Sub-Saharan Africa.

According to the National Food consumption Survey (Labadarios *et al.*, 2000) 93% of children aged between one and nine years consumed maize meal (Table 1.1). In the North-West Province, 100% of the children consumed maize meal. The lowest intake was noted in the Western Cape with intakes of 76%.

Table 1.1 *The percentage of South African children aged 1 – 9 years who consumed maize meal (Labadarios *et al.*, 2000)*

Response(%)	Area of residence (by Province)									
	<i>EC</i>	<i>FS</i>	<i>G/teng</i>	<i>KZN</i>	<i>M/GA</i>	<i>NC</i>	<i>NP</i>	<i>NW</i>	<i>WC</i>	<i>RSA</i>
N	424	208	426	551	164	157	354	232	356	2872
Yes	96	99	95	91	98	99	95	100	76	93
No	4	1	5	8	2	1	5	0	24	7

Key:

EC = Eastern Cape

KZN = Kwazulu-Natal

FS = Free State

NP = Northern Province (Limpopo)

G/teng = Gauteng

NW = North West

M/GA = Mpumalanga

WC = Western Cape

NC = Northern Cape

RSA = Republic of South Africa

It is interesting to find that 92% of the maize was bought from shops in all areas except commercial farms where they possibly produce their own maize meal. In the farming areas of the Free State and Northern Cape 19% and 8% of the respondents were provided maize meal by their farm employers. This means that government can have control of sources of maize for about 92% of the population, which is very high.

The study will provide needed information on the dietary intake of children of Oukasi. This will add to the body of knowledge on food consumption nationally. Such information will be necessary in the formulation of strategies and policies to address the problem of malnutrition.

1.3 THE STUDY AREA

Oukasie is a formal settlement situated 2km East of Brits in the North West Province. It was established in 1928 and it has a deep political history. It was deemed as an illegal settlement from its establishment until 1991. The area is comprised of formal and informal houses, Reconstruction and Development Programme (RDP) houses and squatter camps. Oukasie is fully serviced by the Brits City Council in terms of water, sewerage and emergency services. It has one clinic, one formal crèche, two primary schools and one secondary school. The total number of inhabitants are approximately 500 000 to 800 000.

The area was chosen for this study because:

- Its population stability.
- The presence of the very credible Oukasie Development Trust (ODT) responsible for development in the area.
- It is also a model of many communities that live in urban areas that are in transition from informal settlements to formal settlements.
- The conditions in this area are similar to many other areas in South Africa.

1.4 THEORETICAL ASSUMPTIONS

The following assumptions can be made since maize meal, as a staple, will be fortified:

- Fortification is the cost-effective and long-term solution to micronutrient deficiency in the poor.
- Fortified maize is safe and acceptable to the consumers.

It is also assumed that the study population will consume the maize provided for the study.

1.5 THE AIM OF THE STUDY

The aim of this study was to assess the effectiveness of vitamin fortification of maize meal on the nutritional status of previously undernourished children, aged one to three years residing in Oukasi.

1.6 THE OBJECTIVES OF THE STUDY

The objectives of the study were to obtain baseline information about the study population and to implement an intervention programme.

1.6.1. *Obtain baseline information of the study population*

- Sociodemographic data
- Nutritional status
 - a. Anthropometric measurements
 - b. Biochemical markers of nutritional status
- Nutritional knowledge of the mothers and care givers
- Dietary intake patterns and nutrient intake

1.6.2. *Design and implement an intervention programme*

To evaluate the effectiveness of fortified maize meal, the following had to be done:

- Select 60 stunted or underweight children of which 30 will be randomly assigned to the experimental group and the remaining 30 will be part of the control group (the total number was eventually 44 children who completed the study)
- Provide fortified maize meal to the experimental group and unfortified maize meal to the control group and their families for at least 1 year
- Assess anthropometric and biochemical nutritional status of the experimental and control group at baseline and after 1 year of intervention.

1.7 HYPOTHESIS

It is hypothesized that:

- More than 33% of the children will be vitamin A deficient.
- The experimental group will experience a significant improvement in vitamin A status as compared to the control group after the intervention period.
- The experimental group will show a significant improvement in anthropometric status after the intervention period.
- Maize meal will prove to be an effective vehicle for vitamin fortification.

1.8 DEFINITION OF TERMS

Specific terms used in this thesis, are defined as follows:

- *Stunting*: A child whose height-for-age is below the 5th centile of the National Centre of Health Statistics (NCHS) tables, or minus 2 standard deviations for height-for-age.
- *Underweight*: A child whose weight-for-age is below the 3rd centile of the NCHS tables, or minus 2 standard deviations for weight-for-age.
- *Food security*: Access by all people at all times to the food they need for an active and healthy life.
- *Household food security*: Adequate access by the household to amounts of quality food to satisfy the dietary needs of all of its members throughout the year.
- *Food safety*: Foods that are free of contaminants (microbes, toxins, etc) that may cause diseases.
- *Protein Energy Malnutrition (PEM)*: Malnutrition that results from insufficient intake of energy, protein and other nutrients (vitamins and minerals). Malnutrition in this thesis refers to PEM.

- *Fortification*: Food fortification is a form of food processing which entails the addition of one or more nutrients to a food, to improve its quality for the people who consume it, usually with a goal of reducing or controlling a nutrient deficiency.
- *Vehicle*: The food item which is fortified.
- *Fortificant*: The chemical substance, which in its active form provides the nutrient to be fortified.
- *Nutrition knowledge*: The knowledge of mother/caregiver with regard to breastfeeding practices, introduction of complimentary foods, types of food to be given to the child and the frequency of feeding.
- *Caregiver*: The person responsible to look after the child including feeding, beside the mother.

1.9. THE ORGANISATION OF THE REMAINDER OF THE REPORT

This introductory chapter is followed by a literature review (Chapter 2) which focuses on malnutrition and the role of micronutrients in the causes and consequences of malnutrition. Thereafter strategies to improve the nutritional status of children will be reviewed.

Chapter 3 gives the study design and methods used. The results of the study are given in Chapter 4, while the interpretation of these results is done in the discussion in Chapter 5. Conclusions are drawn and recommendations made in Chapter 6 which is followed by the reference list and addenda.

CHAPTER 2 LITERATURE REVIEW

2.1 INTRODUCTION

This chapter will review available literature on malnutrition, the causes thereof structured according to the UNICEF's conceptual framework, and the prevalence of protein energy malnutrition and micronutrient deficiencies, appropriate intervention strategies and their effectiveness.

The information was gathered from a variety of sources including books, journals and policy documents as well as reports from organisations like the World Health Organisation (WHO), United Nations Children's Fund (UNICEF), World Bank and the Food and Agricultural Organisation (FAO). Journals provided evidence on prevalence in different countries as well as results of different studies on interventions.

The literature review is structured as follows since malnutrition is a broad based problem: Firstly, a general discussion on malnutrition; secondly, the causes and prevalence of malnutrition; thirdly, the micronutrient deficiencies; and lastly, a discussion on intervention strategies.

2.2 MALNUTRITION: A GLOBAL PROBLEM

Malnutrition is a global problem of which children are the primary victims. Protein Energy Malnutrition (PEM), nutritional anaemia, vitamin A deficiency and iodine deficiency disorders are the most serious nutritional problems. South Africa has a high level of malnutrition exhibited by a stunting rate of 23% as well as vitamin A deficiency of public health problem proportion (SAVACG, 1995). It is also sad to note that even in this century, research is suggesting an increase in the prevalence of malnutrition in some parts of the world, including Sub-Saharan Africa. The increase in malnutrition prevalence can be attributed in part to the serious political instability in the region,

resulting in persistent economic crises. Poverty is, therefore, a common feature in the region. This is against the backdrop of the declaration that freedom from hunger is a basic human right (declared in the 1948 Universal declaration of Human rights). The UNICEF conceptual framework (*Figure 2.1*) of the causes of malnutrition indicates that the link between poverty and malnutrition is very evident. Poverty seems to be playing a major role in the development of malnutrition. (SAVACG, 1995)

In South Africa, more than 50% of households are vulnerable to food insecurity (May, 1998). This fact was confirmed by the results of the National Food Consumption Survey which found that 52% of households experience hunger, 23% are at risk of hunger and only 25% of households are food secure (Labadarios *et al.*, 2000). The situation is even worse in the rural areas where 62% of households reported that they experience hunger.

The consequence of poverty will obviously be malnutrition which in turn will result in morbidity and mortality, poor cognitive development, as well poor productivity, and poor pregnancy and lactation outcomes (May, 1998).

Malnutrition and mortality

More than 50 % of childhood mortality in developing countries could be attributed to malnutrition (Beaton *et al.*, 1993). Children that are severely malnourished are 8.4 times more likely to die as compared to well nourished children (Pelletier, 1994). The situation becomes worse if the effect of anaemias and vitamin A deficiencies are factored in. Severe anaemia is found to contribute to 20% of all maternal deaths (Pelletier, 1994). The link between nutrition and mortality will be discussed in detail in later sections.

Malnutrition and morbidity

The interaction of malnutrition and infections is well documented. This is due to the fact that malnutrition lowers the body's resistance to infections and also increases the duration and severity of the infections. On the other hand, infections can, on their own, cause malnutrition due the increased requirements of nutrients and energy, coupled with increased losses as well as

reduction of appetite. The interaction of the two phenomena results in the vicious cycle of malnutrition and infections that could result in death, unless it is broken (Pelletier, 1994).

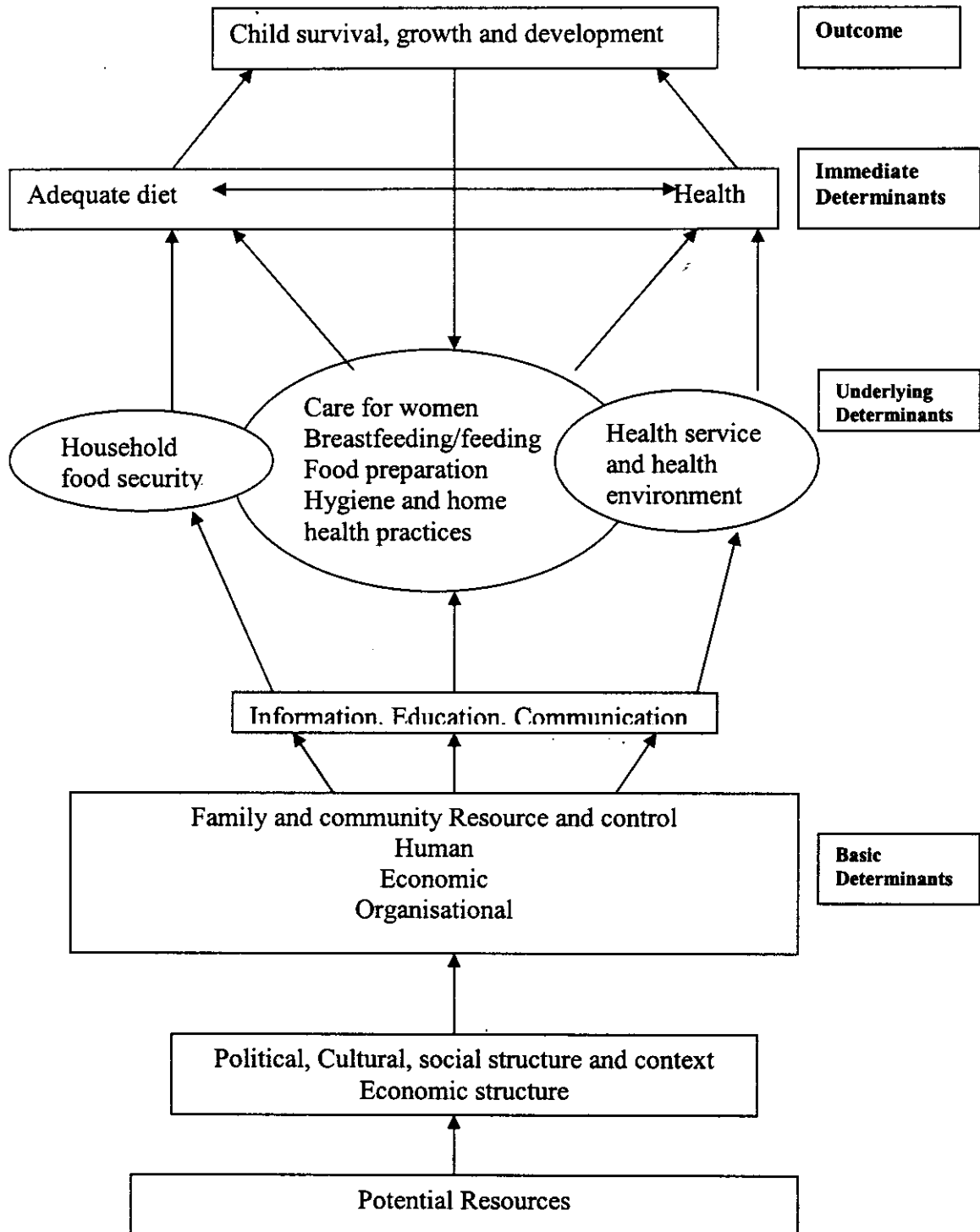


Figure 2.1 Framework for understanding the interlinked causes and consequences of malnutrition (adapted from UNICEF 1998)

Malnutrition and cognitive development and productivity

Poor educational outcomes as well as poor psychological development have long been known to be consequences of severe malnutrition. Schmidt (2001) also documented that even the mild and moderate forms of malnutrition can result in poor cognitive development in children, which could lead to poor productivity later in life. He also confirmed that short-term hunger has a negative impact on the learning capacity of pre-school children. Stunting, which is very common in poor communities, has far reaching consequences since it results in an adult who is short with lower muscle mass, potentially resulting in lower productivity. The low productivity will result in a loss in income, exacerbating the poverty in the household and eventually retarding national economic development (Ross, 1998).

It is therefore evident that poverty results in malnutrition and the consequences of malnutrition manifest themselves in different levels, from households to communities to national and international levels. The causes of malnutrition also operate in different sectors simultaneously. This means that malnutrition is one of the most significant global problems and that mobilization of resources must be implemented at different levels in order to assist countries to alleviate this scourge (Ross, 1998).

2.3. THE CONCEPTUAL FRAMEWORK FOR UNDERSTANDING THE DETERMINANTS OF CHILD SURVIVAL AND DEVELOPMENT.

It is important to discuss at this stage UNICEF's conceptual framework for nutrition (**Figure 2.1**), to understand the interdependence in the causes and consequences of malnutrition.

It is evident that poverty and malnutrition are sequential and interlinked. These elements share a complex relationship. The UNICEF conceptual framework for nutrition is a model, which tries to illustrate the concepts and inter-relationship of poverty and malnutrition. The conceptual framework seeks to

outline the causes of malnutrition, which are presented in three tiers namely immediate, underlying and basic causes. It is important to understand that the framework does not indicate exact relationships, but that it provides a predictive model which shows broad guidelines that will facilitate the identification of causes of the nutritional problem. The discussion on the conceptual framework, which will follow, will be applied in the context of the South African situation, in as much as possible.

Poor dietary intakes and disease (especially infectious) are identified as the most significant immediate causes of malnutrition. As previously discussed, the vicious cycle of malnutrition and infection can immediately result in the deterioration of the nutritional status (UNICEF, 1998). The National Food Consumption Survey found that in general the great majority of South African children consumed a diet that was deficient in energy and had a low nutrient density. As a whole the children consumed < 67% of the nutrients shown in Table 2.1 below:

Table 2.1 Percentage of South African children who consumed < 67% RDA by age
(Labadarios *et al.*, 2000)

Nutrient	1 – 3 years	4 – 6 years	7 – 9 years
Energy	45	47	51
Vitamin A	65	69	79
Vitamin D	93	92	93
Vitamin B6	44	40	34
Ascorbic acid	69	72	70
Riboflavin	39	58	56
Niacin	47	43	38
Vitamin E	66	66	64
Calcium	65	85	84
Iron	79	63	58
Zinc	85	74	72
Selenium	74	67	69

Most important of the above is the deficient energy intake. It is always the case that if a diet lacks energy it will also lack nutrient density since the amount of food consumed will be inadequate. It means, therefore, that in South Africa poor dietary intake is a real immediate cause of malnutrition in children. According to the framework, poor dietary intake is coupled with incidences of poor health and frequent bouts of infections, which can be expected to predispose the children to malnutrition and in turn, make the children more susceptible to other infections. It is unfortunate that those communities that are poor are the ones who are very prominent in the incidences of infectious diseases such as tuberculosis, diarrhoea and fever (South African Health Review, 1996). High prevalence of parasitic infection, notably round worm, whip worm and tape worm have been observed in small studies conducted in Mphumalanga, Kwazulu-Natal and the Western Cape (Vorster *et al.*, 1997). This means that both the immediate causes of malnutrition are simultaneously playing a role in poor (especially rural) communities in South Africa. It is possible to try to intervene by breaking the cycle of infection and malnutrition through short-term strategies, like oral re-hydration therapy. But if long-term solutions are to be found, an analysis of the underlying causes should also be conducted.

As discussed above, poor communities are the ones affected the most by infectious diseases. This is an indication of inadequate maternal and primary health care as well as inadequate access to health care services. The poor access to health care is reflected in the high under-five mortality rates in South Africa, estimated at 68 per 1000 live births compared to 55 in other developing countries (South African health review, 1996). Due to poverty, families tend to find access to health services costly due to transport costs as well as the cost of the treatment itself. This results in these households not seeking medical attention when they are ill.

A recent South African health Review (2002) revealed alarming deterioration in the health status of children. The under-five mortality rate has increased from 59.4 in 1998 to 100 deaths/1000 live births and the infant mortality

increased from 45.4 in 1998 to 59.0 deaths/1000 live births. This could be an indication of poor provision of health care. Another important factor is the impact of the HIV/AIDS pandemic, since the rate of infection in children is also on the increase.

Other services that are found to be lacking in impoverished communities are safe drinking water, proper sanitation and proper housing. On average, 39 % of communities in developing countries do not have access to clean water. In rural South Africa, a third of the households have to walk at least 5km to collect water that is not necessarily clean (May, 1998). This on its own could contribute to malnutrition since the mother's workload will be increased and less time will be available for child care. When considering access to proper sanitation, an even lower percentage has adequate access (May 1998). It is therefore not surprising that diarrhoea is one of the most common causes of child mortality, and that it is a common occurrence in rural communities, where outbreaks of cholera, mainly due to a combination of lack of access to clean water and inadequate sanitation are prevalent. Kwazulu-Natal is a good example of this phenomenon. All these factors combined will eventually result in the health of the children deteriorating, characterized by the presence of infectious diseases. It is therefore important that access to these services be improved, so that the health status of children in these communities can be improved.

On the other hand, inadequate food intake could be due to the inadequate availability of food. As already eluded, 25% of South African households are food insecure. This means that a quarter of South African homes do not have enough food to adequately feed the members of the household. This will obviously result in the weaker members of the household having inadequate dietary intake due to the common misdistribution of inadequate food. The food insecurity in homes can be attributed to the low income where there is not enough money to buy food to adequately feed the household. The less money spent on food i.e. < 60 % of total income will mean that the food consumed in the household will lack variety and consequently also a variety of nutrients. Income on its own is, however, not a good predictor of food

insecurity, since household income will have to be shared with other responsibilities that could be more immediate than food like fuel, transport, schooling, health care and housing. This will be exacerbated by large family sizes in these households (May, 1998).

It is important to achieve food security but it will not on its own achieve the desired nutritional outcomes. There are households that have the means to adequately feed its children and still malnutrition is common. On the other hand, homes that are food insecure are not necessarily going to have children that are malnourished. Attention to the improvement of food insecurity should not deflect the attention to the already discussed issue of health services as well as inadequate care (May, 1998).

Care broadly refers to the meeting of physical, psychological and social needs of household members, especially children. This is achieved through the provision of time, attention and support (Engle *et al.*, 1996). Mental stimulation of children and psycho-social support also positively contribute to nutritional well-being (Gillespie and Mason, 1991). The three main elements found to contribute to proper care includes breast-feeding, education and control over resources. Realising the importance of exclusive breast feeding in providing proper nutrition for infants, it is discouraging to note the fast decline in the practice, especially in the urban areas (Delport, 1999). It is discouraging since stopping breast feeding means early introduction of supplementary feeding which in turn introduces the possibility of pathogens, resulting in diarrhoea. The characteristics of the supplementary food provided tend to be lacking in variety and show low nutritional density which is associated with growth faltering and increased infections (Delport, 1999). The combination of early cessation of breast feeding and early introduction of supplementary feeding could lead to both inadequate dietary intake as well as jeopardising the health status of the children due to the poor sanitation in impoverished communities.

The National Food Consumption Survey (Labadarios *et al.*, 2000) found that the improvement in mother's educational level was associated with significant

reduction in the prevalence of stunting, underweight and wasting in all age groups. This means that efforts should be made to empower the mother with knowledge and information pertaining to childcare. This will support the improvement of the underlying causes of malnutrition, as discussed earlier.

The basic causes of malnutrition in communities relate to both the historical background of the society and factors external to the society. In simple terms, this implies the allocation and control over resources in the society and thus the structural causes of poverty and inequality. In South Africa, economic and social policies of the apartheid era resulted in the allocation and control of societal resources in the hands of the minority. This resulted in poverty in the black communities since these communities were financial disfranchised. It further resulted in communities, especially in rural areas, which were never developed, where the prevalence of malnutrition is now most common. The least developed of the communities are the ones in the Provinces who up to today exhibit high prevalences of malnutrition, viz. Eastern Cape and Limpopo Province. Three quarters of the population in these provinces are regarded as poor, with a poverty rate of above 70% (Labadarios *et al.*, 2000).

Past discriminatory policies have led to situations in which poverty also cuts across colour lines in South Africa. This is because poverty levels are high amongst Africans and coloureds, compared to whites and Indians (Labadarios *et al.*, 2000).

Looking at the conceptual framework (Fig 2.1), South Africa has a serious problem of malnutrition cutting across all levels of causes. Stunting rates are high among the disadvantaged communities. Malnutrition in South Africa is related to poor people's living conditions and the social and psychological consequences of poverty, as to the economic dimension of poverty. It is, therefore, more of a national problem than an isolated localised problem.

In the rest of the chapter the prevalence of malnutrition and micronutrient deficiencies and the intervention strategies to combat nutritional deficiencies will be discussed.

2.4 THE PREVALENCE OF NUTRITIONAL DEFICIENCIES IN CHILDREN

2.4.1 Protein Energy Malnutrition

It is well accepted that South Africans suffer from a double burden of disease, i.e. undernutrition, which affects mostly rural African children, and over-nutrition, which affects mostly urban children (Labadarios *et al.*, 2000). The results of the National Food Consumption Survey are summarized in **Table 2.2** below.

Table 2.2 *The anthropometric status of South African children age 1 – 9 years by age groups (Labadarios et al., 2000)*

<i>Anthropometric Parameter</i>	<i>1 – 3 years</i>	<i>4 – 6 years</i>	<i>7 – 9 years</i>	<i>National</i>
<i>Number (n)</i>	1198	975	440	2613
<i>% H/A < - 2SDs</i>	25.5 <i>23.0 – 27.9*</i>	20.7 <i>18.2 – 23.3</i>	13.0 <i>9.8 – 16.1</i>	21.6 <i>20.0 – 23.2</i>
<i>% W/A < - 2SDs</i>	12.4 <i>10.5 – 14.2</i>	8.8 <i>7.0 – 10.6</i>	7.7 <i>5.2 – 10.2</i>	10.3 <i>9.1 – 11.4</i>
<i>% W/H < - 2SDs</i>	4.0 <i>2.9 – 5.1</i>	3.4 <i>2.2 – 4.5</i>	3.4 <i>1.7 – 5.1</i>	3.7 <i>3.0 – 4.4</i>

** Confidence interval*

H/A = Height-for-age; W/A = Weight-for-age; W/H = weight-for-height

At national level the prevalence of stunting is still the most prevalent disorder affecting 22% of the children. The most affected were children residing in farms and rural areas and the least affected were children in the urban areas. It was also notable that stunting was high in the age group 1 – 3 years (26%) as compared to age groups 4 – 6 years and 7 – 9 years, with a prevalence of 21% and 13 % respectively. The same trend was observed to a lesser extent for

underweight but not for wasting. For the purpose of this discussion, attention will be paid to the age group that is most affected viz. 1 – 3 years (Labadarios *et al.*, 2000). The prevalence of PEM by province for the age group 1 – 3 years is indicated in **Table 2.3**.

Table 2.3 *The anthropometric status of South African children aged 1 – 9 years by province (Labadarios et al., 2000)*

Anthropometric Parameter	EC	FS	G/teng	KZN	M/G	N/Ć	NP	NW	WC
Number (n)	381	203	411	465	144	135	321	229	324
%H/A < -2SDs	20.5 16.4-24.5*	29.6 23.2-35.9	20.4 16.5-24.4	18.5 15.0-22.0	26.4 19.1-33.7	29.6 21.8-37.4	23.1 18.4-27.7	24.9 19.2-30.5	14.5 10.7-18.4
%W/A < -2SDs	7.1 4.4-9.7	14.3 9.4-19.1	8.8 6.0-11.5	6.0 3.9-8.2	4.2 0.9-7.5	23.7 16.4-31.0	15.0 11.0-18.9	15.3 10.6-20.0	8.3 5.3-11.4
% W/H < -2SDs	1.8 0.4-3.2	3.4 0.9-6.0	1.2 0.2-2.3	4.3 2.5-6.2	2.8 0.1-5.5	9.6 4.6-14.7	7.5 4.6-10.4	5.7 2.7-8.7	0.9 0.0-2.0

* *Confidence interval*

The common determinants of growth are known to include dietary intake, maternal child health as well as infections (Waterlow, 1994). In terms of dietary intake much emphasis is placed on total energy intake and to a lesser extent on the quality of protein consumed (Golden, 1988). Much of the emphasis was previously placed on protein from animal products. It has become evident that the nutrient density of the diet should be the main issue as it looks at both energy for growth and will also give a measure of variety of the micronutrient content of the diet. Protein from plant products consumed in a varied diet would be adequate to meet the dietary requirements of children.

Table 2.4 *A Comparison of the status of children in South Africa, with that of children in other African countries, South America and Asia (UNICEF, 2000).*

Country	GNP/Capita (US\$1997)	Stunting #	Underweight #	Wasting #
South Africa*	3210	30	12.4	4.6
Ethiopia	110	64	48	8
Burundi	140	43	37	9
Tanzania	210	42	27	6
Malawi	210	48	40	7
Uganda	330	38	26	5
Bhutan	430	56	38	4
Nigeria	280	43	36	9
Bangladesh	360	55	56	18
India	370	52	53	18
Zambia	370	42	24	4
Ghana	390	26	27	11
Nicaragua	410	25	12	2
Pakistan	500	38	n/a	n/a
Lesotho	680	44	16	5
Zimbabwe	720	32	15	6
Bolivia	970	36	10	2
Egypt	1200	25	12	6
Guatemala	1580	50	27	3
El Salvador	1810	23	11	1
Namibia	2110	28	26	9
Botswana	3310	29	17	11
Brazil	4790	11	6	2

* Children aged 1 – 6 years; n/a Not available;

Data from other countries refer to children under five years as combined, moderate and severe. Percentages of children in different categories are indicated. The prevalence of stunting and underweight in South Africa is

indicated in **Table 2.4** above, South Africa seems to be struggling in terms of controlling the prevalence of under-nutrition, considering the (Gross National Product) GNP/Capita of US\$3210. Countries like Ghana, Egypt, Namibia and Nicaragua, with a GNP of less than half of that of South Africa, had lower prevalences of stunting. This means that South Africa has the means to deal with the scourge of under-nutrition.

Several isolated and small studies were done in different regions in Africa, to determine the prevalence of PEM, using different parameters. The results of these studies are summarized in **Table 2.5** below:

Table 2.5 *A summary of isolated studies done in African and Asian Countries to determine the prevalence of PEM (Sources *)*

Country	Prevalence (%)	Age group	Parameter	Researchers
Senegal	44	6 – 29month	General	Toure <i>et al.</i> (1998)*
Ethiopia	36	<5 yrs	W-A	Getarch (1998)*
	9		W-H	
	36		H-A	
Bangladesh	50	<5 yrs	W-A	Ahmed (1992)*
Egypt	14	6 – 12 yrs	W-A	El Gendy & Abdel-Rehim (1992)*
	37		H-A	
RSA	18	6 – 12month	H-A	Oelofse (2001)*
WP	7	6 – 12month	W-A	

WP = Western Cape RSA = Republic of South Africa

Judging by the results of the Food Consumption Survey (Labadarios et al., 2000), priority should be given to children below the age of 3 years. Intervention should be prompt seeing that the consequences of stunting will have far reaching implications in terms of poor mental development, which might influence the overall productivity of the country, as well as morbidity and mortality (Waterlow, 1994).

Apart from the well-documented prevalence of PEM in South Africa, there is adequate evidence available on the high prevalence on vitamin A deficiency, which is a public health problem. It is therefore proper to discuss vitamin A deficiency at this stage, especially since the coexistence of PEM and vitamin A deficiency is well established.

2.4.2. *Vitamin A deficiency*

Vitamin A deficiency is diagnosed in terms of concentration of retinol in serum. The World Health Organisation (WHO) classifies the deficiency as follows:

Table 2.6 Classification of vitamin A deficiency, using serum retinol as an indicator (WHO, 1995).

Plasma retinal		Classification
Less than 10µg/dl	< 0.35µmol/l	vitamin A deficiency
10 – 19.9µg/dl	0.35 – 0.7µmol/l	Marginal vitamin A deficiency
20 – 29.9µg/dl	0.7 – 1.05µmol/l	Adequate
>30µg/dl	>1.05µmol/l	Normal

It is estimated that 250 million young children suffer from vitamin A deficiency worldwide. This is known to contribute to high morbidity and mortality in young children from developing countries (Malanick, 1999).

Several factors play a role in the development of vitamin A deficiency. Socio-political and economic systems, at macro level, result in unavailability of land to the affected population. Other political factors may include war, misdistribution of arable land and inadequate health and social services. Natural factors like drought and intense rain, result in an inadequate supply of food (WHO, 1995).

Ecological factors such as improper sanitation, unavailability of safe drinking water and poor waste management, also play a significant role at micro level. Other issues include: overcrowding, poor personal hygiene, unemployment, poverty, and inadequate health care. All these micro factors expose the affected household or community to infections (WHO, 1995). A household or community with inadequate supply of food and exposure to infection, is likely to face children with vitamin A deficiency and PEM.

Alnwick (1998), showed a global prevalence of vitamin A deficiency. **Table 2.7** depicts this prevalence from representative surveys ranging from 6% in Panama to 78 % in Lesotho. It is evident from the table, that vitamin A deficiency is a serious problem in many countries of the world. Vitamin A deficiency of public health proportion, is a problem in the last 8 countries, including South Africa.

It is notable from the table, that the prevalence of vitamin A deficiency in South Africa is unacceptably high for a country of its financial stature. Even poorer countries like the Dominican Republic and Costa Rica have prevalence's that are lower than that in South Africa.

It can be assumed that those countries with a lower GDP than South Africa have lower prevalence and good policies to deal with the deficiency. There could also be different ways, which they implemented to counteract the macro, and micro factors that predisposed their communities to vitamin A deficiency. South Africa has a lot to learn from these countries.

Table 2.7 *The global prevalence of vitamin A deficiency (serum retinol <0.7 mmol/l) from nationally representative surveys (1992 – 1996). Alnwick (1998)*

Country	% Prevalence	Year of survey
Panama	6	1992
St Vincent	6.5	1996
Venezuela	7	1994
Costa Rica	8	1996
Nigeria	8.5	1993
Mauritius	8.7	1995
Dominican Republic	9	1996
Philippines	10	1993
Antigua	11	1996
Egypt	12	1995
United Kingdom	12	1992
Ecuador	18	1993
Oman	21	1995
Botswana	32	1994
South Africa	33	1994
Kenya	33	1994
Ivory Coast	36.5	1994
Ethiopia	38	1996
Micronesia	44	1992
Marshall Islands	55	1994
Lesotho	78	1993

Other researchers performed studies to determine vitamin A deficiency in their own countries (Table 2.7). The degree of the problem varies from country to country and it is evident that the less developed the country, the higher the prevalence of the deficiency. This can be explained by the discussions on the framework for nutrition, discussed earlier in the chapter.

Table 2.7 confirms that vitamin A deficiency is common in countries with high prevalence of PEM. It is also known that micronutrient deficiencies rarely occur singularly. It is common that communities tend to suffer from multiple micronutrient deficiencies (Rosado, 1999)

Table 2.8 *The prevalence of vitamin A deficiency, in different countries.*
*Sources**

Country	Prevalence	Age group	Parameter	Researchers
Nigeria	11,3	3 – 57 months	S retinol	Adelkan <i>et al.</i> (1997)*
France	<5	<5 yrs	S retinol	Malvy <i>et al.</i> (1989)*
El Salvador	36	<5 yrs	S retinol	Malvy <i>et al.</i> (1989)*
Chile	25	<5 yrs	S retinol	Malvy <i>et al.</i> (1989)*
Cameroon	71,7	3 – 5 yrs	S retinol	Gouado <i>et al.</i> (1995)* Bloem <i>et al.</i> (1989)*
Thailand	12,7	1 – 8 yrs	S retinol	Farbos <i>et al.</i> (1995)*
Mali	31,4	3 – 7 yrs	Cytology	Kafwembe <i>et al.</i> (1996)*
Zambia	78	7 – 29 months	MRDR	VAST study (1996)*
Ghana	42	<5yrs	S retinol	Rahi <i>et al.</i> (1995)*
India	18,6	3 – 15 yrs	Visual impairment	Rosen <i>et al.</i> (1994)*
Yemen	63%	1 – 5 yrs	S retinol	

The coexistence of PEM and micronutrient deficiencies confirms the notion that food insecurity is common in underdeveloped communities that are affected most by undernutrition. It is, therefore, important that interventions planned for these communities should start with the improvement of food security before considering nutrient security. Vitamin A deficiency is also common in younger children. An intervention is not effective in children from high socio-economic grouping, thus underscoring the importance of targeting as well as the need to take a more comprehensive nutritional approach as opposed to just concentrating on a single micronutrient intervention (Rosando, 1999).

In South Africa, the prevalence of vitamin A deficiency was highlighted with the SAVACG study (1995). The study indicated that South Africa has a public health problem when it comes to the prevalence of sub-clinical vitamin A deficiency (Table 2.9). Another study confirmed this problem (Faber & Banade, 2000).

Table 2.9 *Vitamin A status of children aged between 6 and 71 months: The SAVACG study by age group (SAVACG, 1995)*

Serum Retinol (µg/dl)	6 – 11 months	12 – 23 Months	24 – 35 Months	36 – 47 Months	48 – 59 Months	60 – 71 Months
Number (n)	204	620	766	917	914	776
Mean	24.9	25.1	24.0	23.3	23.4	24.0
Confidence interval	25.5 – 26.4	24.0 – 26.1	23.1 – 24.9	22.5 – 24.0	22.6 – 24.2	23.2 – 24.9
% 0 – 9µg/dl	2.4	3.3	3.0	3.2	4.1	3.2
% 10 – 19 µg/dl	21.9	26.5	31.1	33.9	30.8	28.3
% 20 – 29 µg/dl	55.1	43.1	42.7	43.5	42.3	47.8
% 30 – 39 µg/dl	16.0	20.2	18.5	16.2	20.0	16.7
% 40 – 49 µg/dl	3.9	6.4	3.8	2.6	2.1	3.4
% 50+ µg/dl	0.7	0.5	0.9	0.6	0.7	0.6
% < 20µg/dl	23.4	29.8	34.1	37.1	34.9	31.4

Severe forms of vitamin A deficiency (<10µg/dl) have a prevalence ranging from 2.4 to 4.1%, with the highest prevalence in the age group 4 to 5 years. The prevalence of sub-clinical vitamin A deficiency ranges from 23.4 to 37.1%, with the highest prevalence in the age group 3 to 4 years.

The prevalence by province was as follows in descending order of prevalence (SAVACG, 1995):

- 43% Limpopo
- 38% Kwazulu – Natal
- 33% Mpumalanga
- 32% North West
- 31% Eastern Cape and
- 18% Northern Cape

The prevalence in all the provinces is above 30%, except for the less populous Northern Cape Province.

Clinical forms of vitamin A deficiency were also found during the SAVACG study. The prevalences reported were:

- Night blindness 12%
- Bitot's spots 0.4 – 0.8%
- Corneal Xerosis 0.2 – 0.7 %
- Corneal Scar 0.1%
- Xerophthalmia <0.06%

According to the SAVACG (1995) study, only 16 to 20 % of the children had normal vitamin A status.

The need for the intervention is clear and the most effective strategy in the long term will be the most suitable to address the problem in South Africa. This is made worse by the fact that the dietary intake of vitamin A amongst children in

South Africa is very poor (Labadarios *et al.*, 2000). Between 65 and 79% of children aged 1 – 9 years, consumed less than 67% of the recommended allowances for vitamin A. It is also worse if one considers that between 55% and 68% of these children consume less than half the RDA s. If one considers the cost of vitamin deficiency through blindness, growth faltering and increased number and severity of infections, it is therefore necessary that a strategy that will increase these intakes at low cost, is seriously considered.

2.4.3 Iron deficiency

Most recent research on iron, concentrated on interventions with the understanding that the prevalence of iron deficiency and the gravity of the problem of iron deficiency, have been well established. The information of iron deficiency presented below, is from studies conducted in the 80's and 90's.

Global prevalence

Of all nutritional deficiencies present today, iron deficiency is by far the most prevalent (DeMaeyer & Adiels-Tegman, 1985). Due to the complexity of its diagnosis, no direct global assessment has been done. Present statistics have been estimated from the prevalence of anaemia, since iron deficiency is known to be one of the major causes of anaemia.

The WHO reviewed the prevalence of anaemia from 1960 to 1984, throughout the world, and yielded very important findings. Groups at risk for anaemia were young children below the age of 5 years and pregnant women with a prevalence of 43% and 51% respectively. The third most affected group was school going children (37%). Adult males and females had an estimated prevalence of 18% and 35% respectively (DeMaeyer & Adiels-Tegman, 1985).

This study was unable to obtain enough information from the adolescents or the aged, but the prevalence of anaemia in adolescents is presumed to be close to that of adults in respect to gender. The regions with the highest overall prevalence were South East Asia and Africa. This is likely to be due to the low

socio-economic level of these regions. The prevalence was highest in women with a prevalence of 65% (DeMaeyer & Adiels-Tegman, 1985).

Hercberg & Galan (1992) estimated that 1300 million people globally, suffer from anaemia, especially in developing countries. Seventy percent of this number (600 – 700 million), is estimated to be affected by iron deficiency anaemia. It is however, important to note that iron deficiency is more common compared to overt iron deficiency anaemia. These values are echoed by the WHO study, which reported that the figures were an underestimation of the real situation, though they are still impressive if the implications of iron deficiency anaemia are taken into consideration.

Local prevalence

Most of the studies conducted in South Africa were limited to the groups known to be at risk of developing iron deficiency, namely infants, children and pregnant mothers.

Lamparelli and co-workers (1988) investigated the prevalence of anaemia in 11 year old children in the Western Cape. They found that the mean Haemoglobin (Hb) value was 13.0 ± 1.2 g/dl. Coloured and black children exhibited low mean Hb levels compared to those of white children (12.2 ± 1.2 g/dl vs. 13.4 ± 1.0 g/dl. Rural children exhibited lower mean serum ferritin levels compared with those of urban children.

The black population of the Western Cape was also found to exhibit a high prevalence of iron deficiency and iron deficiency anaemia. In the age group 15 – 24 years, 15.5% were found to be iron deficient. In the age group 15 – 24 years, 15.5% were found to be iron deficient and 11.3% and 22.0 % (males and females respectively) were found to have iron deficiency anaemia (Nesamvuni 1995).

The SAVACG study (1995), surveyed 11430 children aged 0.5 to 6 years and found the prevalence of iron deficiency as indicated in **Table 2.10**.

Table 2.10 The prevalence of iron deficiency among South African children aged 6 – 71 months (SAVACG, 1995)

Parameter for diagnosing Iron deficiency	Prevalence (%) of deficiency in SA children
Hb (<11g/dl)	21
Ferritin (<12ug/l)	10
MCV (<73fl)	17
Hb <11 + Ferritin <12	5
Hb <11 + Ferritin <12 + MCV low)	3

* SAVACG report 1995.

Hb = Haemoglobin; MCV = Mean Cell Volume

The prevalence of anaemia was unacceptably high at 21% as well as the prevalence of iron deficiency at 10%. Although there was a high prevalence of the two moderate conditions, only 3 % suffered from iron deficiency anaemia.

The high prevalence of iron deficiency is made worse by the poor intake of iron as depicted by the National Food Consumption survey. Between 58 to 79 % of children, aged between 1 and 9 years, consumed less than 67% of RDA. The worst case scenario is the fact that 41 to 63 % consumed less than half of the RDA. It must also be understood that the iron consumed by these children is of very low bioavailability, such that if one only considers the intake of high bioavailability iron, the situation could be worse. It is known that the simultaneous consumption of vitamin C with low bio-available iron improves its absorption (Bothwell at al., 1989 and Cook *et al.*, 1991). This is, however, not promising since the overall consumption of vitamin C was low. Between 69 and

72% of children aged 1 – 9 years consumed less than 67% of RDA for vitamin C and 61 to 63% of these children consumed less than half of the RDA.

Apart from the poor intakes of iron, there is also another problem of helminth infestation. According to Haffejee *et al.* (2000), primary school children in the Cape Peninsula exhibited prevalence of whipworm and roundworm infestation of 80.3 % and 69.7% respectively. Schistosomiasis can also adversely affect iron status through blood losses caused by ulceration (Gillespie & Johnston, 1998). The eradication of such infestations is recommended since it might hamper the effectiveness of nutritional intervention that may be instituted.

It is evident that protein energy malnutrition, as well as micronutrient deficiency, are still very common in the developing world, including South Africa. Although the prevalence shows a marked degree of reduction, the figures are still troubling, considering the consequences of these deficiency conditions. Different types of interventions have been implemented in different countries, with varying results. Something needs to be done! It is also evident that PEM and micronutrient deficiency co-exist in many more instances than occurring individually. This also shows that there is still a shortage of energy and micronutrient supply in underdeveloped areas, mainly due to food insecurity.

2.4.4 The consequences of micronutrient deficiencies

Treatment of malnutrition results in a major financial drain of any national economy, especially the health budget. The World Bank, (1994) estimates that economic losses that can be attributed to malnutrition range from 6 – 12% of the GNP of developing countries. Therefore, South Africa is loosing a minimum of 6%. It can be estimated that ~ 4 billion is lost due to malnutrition (SAVACG, 1995).

Scrimshaw (1990), in his review, highlighted the consequences of iron deficiency anaemia as follows:

- Congestive heart failure
- Increased susceptibility to infections
- Poor physical growth
- Reduced work and mental performance
- Retardation of psychomotor development and
- Reduced learning capacity in infants.

These consequences and the fact that they affect mostly children and also that long term learning retardation might be irreversible, is frightening. It is also frightening when one considers the effect this will have on the economy of developing countries (Ross, 1998). It is estimated that a reduction of Hb by 1% has a resultant reduction in work output of 1.5%. This means that the economic output of a country can be reduced by 5- 7% if the prevalence of anaemia is 50% in women and 20% in men (Davidson and Stoltzfus, 2000).

Vitamin A deficiency is closely linked to increased frequency and severity of infections. This means that if the deficiency is not curbed more and more children will suffer from infectious diseases such as measles, malaria and diarrhoea (Sommer, 1990). They are also likely to contract the severest form of vitamin A deficiency, with high of mortality rate (Sommer *et al.*, 1986). There is evidence that the improvement of vitamin A status have reduced the mortality by 23% (Alnwick, 1998).

In addition, vitamin A has also been linked to blindness (SAVACG, 1995 citing Stephenson and Clark, 1920). This is a concern when one considers the number of children who go blind or have impaired vision due to vitamin A deficiency.

It is imperative that these deficiencies be eradicated, since the cost of dealing with their consequences far outweighs the cost of eradicating the deficiency.

SAVACG (1995) concluded that the prevention of malnutrition and its negative effects on the quality of individual and community life, together with the implication for national productivity and socio-economic development, are the strongest arguments for any government to afford this the highest priority.

2.5 THE RELATIONSHIP BETWEEN STUNTING, UNDERWEIGHT AND MICRONUTRIENT DEFICIENCY

It is very common that discussions on PEM and micronutrient deficiencies are done as if the two conditions occur in isolation. This section seeks to confirm the coexistence of general PEM and micronutrient deficiencies. This section will review only those studies that elicit the coexistence of the two conditions.

It is known that multiple deficiencies are common in developing countries. In South Africa, the SAVACG study (1995) found that children aged between 6 and 71 months, suffered from marginal vitamin A deficiency, to the extent of public health proportions. This deficiency was also found to coexist with a marked prevalence of stunting. This does not seem to be isolated since a study conducted in the informal settlements in Kwazulu-Natal (Coutsoudis *et al.*, 1994) confirmed a significant positive correlation between PEM and poor vitamin A and iron status. Dudley *et al.* (1997) found that apart from factors such as previous diarrhoeal disease, severity of disease and poor housing, a low weight-for-age was one of the factors associated with poor vitamin A status.

In another South African study (Oelofse *et al.*, 1999), it was found that rural communities show a high prevalence of anaemia (24%), marginal vitamin A deficiency (45%) and iodine deficiency (32%). Deducing from these studies, it can be expected that if anthropometric measurements were done in these studies, a high percentage of the children would either have been stunted or underweight.

Apart from an established link between growth and vitamin A deficiency, it has also been found that growth is improved when children are supplemented with iron (Commey & Dekyem, 1995) and vitamin A (Coutsoudis *et al.*, 1991).

In Namibia, Jooste *et al.* (1994) found that primary school children in the Caprivi region showed undernourishment, and low weight and height-for-age ranging from 38 to 56 %. This, however, existed together with a prevalence of 35% of goitre and 34 to 43 % of biochemical anaemia.

The coexistence of PEM and micronutrient deficiency can be attributed to the quality of the diet consumed by populations found to suffer from these deficiencies. The diet consumed in developing countries is usually monotonous, with very little or no variety and also deficient in nutrient density. This basically means that the total energy consumed tends to be inadequate to support growth. The quantity and bioavailability of the micronutrients are very low and, therefore, inadequate to meet the needs of children in a growing phase. In the previous sections it was pointed out that communities that suffer the most from PEM tend to be more likely to suffer from infections due to poor sanitary conditions in the households. The presence of infections will cause inadequate intake of food, an increase in nutrient losses as well as increased requirements, eventually resulting in micronutrient deficiency (Tarini *et al.*, 1999)

Tarini *et al.* (1999) found that energy, protein and zinc were positively and significantly correlated with anthropometric status. Both dietary quality and diversity of food eaten were determinants of growth. Therefore, the assessment of dietary quality can be used as an indicator without even considering specific nutrients.

2.6 INTERVENTIONS AGAINST MALNUTRITION

2.6.1 *The need for a holistic approach*

It is already evident that any intervention on malnutrition should begin with the basic causes if lasting outcomes are to be achieved. The identification of the basic causes and intervention at global level has led to several successes in many countries (UNICEF, 2000)

In South Africa, the political ideology of the past has contributed to the fact that certain areas have high levels of food insecurity, poor care for mother and child as well as poor health services due to deliberate underdevelopment in the affected areas. The Limpopo Province and the Eastern Cape are the most affected. The National Food Consumption Survey (Labadarios *et al.*, 2000) confirmed that these two provinces have the highest incidents of PEM in the form of stunting and underweight. This then means that the type of intervention that is implemented should be holistic in nature, taking into consideration the basic causes of malnutrition, which are imbedded in existing poverty and its contributing factors.

Most interventions that have been instituted, experimented with improving the dietary intake by improving the nutritional composition of the diet through fortification, supplementation and diversifying the types of food consumed. Some studies go to the extent of influencing the health status through public health interventions like deworming. Interventions like the iodine fortification of salt in South Africa, have been found to be very effective at study level and some at national level (Jooste *et al.*, 1995) It is however, worth noting that if the underlying causes and the basic causes are still in place, they will affect the intervention strategies negatively; the same way that they influenced normal food supply to the affected communities. According to UNICEF, ending malnutrition requires a simultaneous response to many of its causes (UNICEF, 2000). Two countries, namely Tanzania and Thailand, proved that political decisions can make a major impact without even implementing direct nutritional

intervention. Both countries managed to eradicate severe PEM through a government decision to implement growth monitoring which was followed by an improvement in the understanding of factors involved in nutritional well-being, the improvement of an understanding of the prominence of nutrition, as well as direct intervention in communities that needed supplementary feeding. Other strategies that were then implemented were the increase in feeding frequency, training of health workers, and improving treatment of diarrhoea, supporting home farming and improving sanitation. All of these stemmed from a national decision to initiate growth monitoring. This allowed the community to make better use of the available resources (UNICEF, 2000). The success in Thailand was the reduction of mild to moderate PEM from 51 to 19% over 8 years (UNICEF, 2000).

Of crucial importance in the Tanzania and Thailand examples was the Government's continued commitment, even during difficult times. It is interesting to note that in Tanzania there was no need to increase food production or the availability of basic food. This confirmed that the lack of food at household level was not the major cause of malnutrition. Of singular importance was the transformation of the community, starting at national government level which led to a high level of political mobilisation resulting in a more organised communication system (UNICEF, 1998).

Lastly, it is also worth noting that the economic position of Tanzania, especially, did not change. Though economic growth is known to contribute to nutrition improvement through the improved quality of food consumed, it is, however, not a necessary condition for nutrition improvement (UNICEF, 1998)

In conclusion, it is important to realise firstly, that PEM and micronutrient deficiency coexists in underdeveloped countries and that a comprehensive model of intervention is advisable. It is also notable that if the model is implemented, it will be possible to reduce both PEM and micronutrient deficiencies simultaneously, leading to a better national nutrition picture. Secondly, the intervention should be backed by a strong political drive that will ensure that any direct nutritional intervention that is implemented will not be

caught in a bureaucratic web. This will also ensure the mobilisation of available as well as more organised communication processes. Thirdly, it is to be noted that food insecurity is the key underlying cause of undernutrition and is often the pivotal point in the relationship between economic growth and nutritional status. Fourthly, UNICEF (1998) rightfully concluded that in countries where nutrition improvement has lagged behind economic growth, discrimination against women is common. Improving the literacy, participation and understanding of factors involved in nutrition by women will yield dramatic results as shown in Tanzania and Thailand.

A detailed discussion of direct nutritional interventions that can be implemented for the eradication of micronutrient deficiency, will follow in the next section.

2.6.2. *Direct intervention strategies*

2.6.2.1 *Introduction*

There are many micronutrients (>30) which are regarded as essential for the growth and development of children. There was a pledge signed by many heads of states early in the 90's to eliminate vitamin A and iodine deficiencies and substantially reduce iron deficiency by the year 2000 (UNICEF, 1990). Each country, even regions, employed different strategies to fulfil the pledge.

The strategy could either be comprehensive or targeted (UNICEF, 1990). A comprehensive approach would include the following:

- Public health measures
- Horticultural activities
- Treatment and control of diseases and infections
- Improvement of food security
- Poverty alleviation
- Fortification and the use of
- Supplements.

A narrowly targeted approach would include a distribution of capsules containing the micronutrients to high risk groups like small children.

There are four basic micronutrient strategies, which will be discussed in detail.

These are:

- Food fortification
- Supplementation
- Food diversification
- Public Health Measures

These four strategies differ in their extent of sustainability. A detailed review of each of the four strategies will follow.

2.6.2.2 Food fortification

Food fortification is a form of food processing which entails the addition of one or more nutrients to a food to improve its quality for the people who consume it, with a goal of reducing or controlling a nutrient deficiency (Latham, 1997). Lately the word fortification is used interchangeably with food enrichment. Earlier, in some circles, the differentiation was the fact that enrichment entailed adding a nutrient that is native to the food vehicle whereas fortification was regarded as the addition of a nutrient that is not native to the vehicle. At the end of the day the goal remained the reduction or control of nutritional deficiency and that is where the interest of this study lies (Latham, 1997).

Food fortification can be the most effective strategy as proved in the industrialised world, if the right food vehicle is chosen and high coverage assured. In Britain and Northern Europe, rickets were virtually eliminated through the fortification of margarine with vitamin D. The dramatic reduction of anaemia in the United States and Sweden was credited to the fortification of

flour with iron (World Bank, 1994). There is, however, a major challenge of duplicating these impressive results in developing countries. The major cause of poor outcomes is usually attributed to not following the correct principles of fortification (World Bank, 1994). The principles are captured in the eight steps for successful food fortification, namely:

- (i) Justification on the basis of data showing the prevalence, distribution and seriousness of the problem
- (ii) Consideration of other methods to control the deficiency, such as food diversification
- (iii) Advocacy to educate government decision-makers, the food industry and the public and to obtain their feedback and co-operation
- (iv) Selection of the food or foods to be fortified and of the form of nutrient/s to be added
- (v) Actions related to implementation, including establishment of an interdisciplinary team to work with the food industry involved and the micronutrient supplier, and determination of a time frame for implementation
- (vi) Consideration of budget and organizational aspects
- (vii) Development of legislation and other regulatory aspects
- (viii) Establishment of a system for evaluation and continuous monitoring.

Other considerations up and above the stepwise procedure detailed above include (World Bank, 1994):

- Wide consumption of the food to be fortified among the at risk group
- Suitability of the food and nutrient together
- Technical feasibility
- Limited number of food manufacturers
- No substantial increase in price of the food
- Range of consumption of the food.

If all the above are not taken into consideration, it is very likely that the programme would fail, not because of the nutritional quality, but due to logistical challenges. One other entity that can ensure success is the participation as well as education of the consumer. This should encourage the population to purchase the fortified food, which could be strange to them, regarded as unnatural, or may even be slightly more expensive than the unfortified competitor. All of these challenges can be addressed by ensuring that the population is well educated and informed about the fortification programme. Similarly with supplementation, the involvement of the government will also facilitate in the organisation of the communication strategy (World Bank, 1994).

2.6.2.3 The effectiveness of fortification as an intervention for micronutrient deficiency

Fortification has been noted for its success in eliminating vitamin and mineral deficiencies (Latham, 1997). Several vehicles have been tested including, biscuits, rusks, milk, salt, water, wheat and maize flour. It is therefore important that these studies are reviewed to establish the possible effectiveness of this strategy for South Africa.

A study was conducted by Liu *et al.* (1993) over a period of 3 months in rural Beijing. The vehicle was a rusk, which was fortified with iron, zinc, calcium, vitamins A, D and B12, thiamine, riboflavin, niacin and folic acid. It was found that the children who received unfortified rusks exhibited a significant decline in haemoglobin. Interestingly though, both groups showed a marked improvement in erythrocyte porphyrin, serum retinol and riboflavin. This study proved the fact that the fortification of rusks can be beneficial to iron status. The study must, however, also be looked at in terms of its duration. Three months might not be long enough to expect significant changes.

In South Africa a fortification study that received a lot of accolades was the fortification of curry powder with iron which resulted in positive outcomes (Ballot *et al.*, 1989). Another study was the multiple fortification of biscuits with iron, iodine and beta-carotene (Van Stuivenberg *et al.*, 1999). In the biscuit study, 115 children aged 6 to 11 years were randomly placed in two different groups. One group was receiving a fortified biscuit and the other a non-fortified biscuit. The results obtained showed a significant ($p < 0.0001$) improvement in all the micronutrients that were fortified viz. serum iron, transferrin saturation, serum retinol, serum ferritin and urinary iodine. The prevalence of low serum retinol and serum ferritin concentrations was reduced from 39.1% to 12.2% and from 27.8 % to 13.9% respectively. This was accompanied by the reduction of the prevalence of anaemia from 29.6% to 15.6% as well as the reduction of low urinary iodine from 97.5% to 5.4%. There was also a significant difference ($p < 0.05$) in the cognitive function of both groups of children. This is a strong case for the effectiveness of fortification over a period of 43 weeks.

Latham and co-workers (2001) did another fortification study in Tanzania, using a combination of nutrients. They added iron, vitamin A and iodine in fruit juice powder. In this study, school going children were given 25grams of fruit flavoured powder mixed in 200ml of water per day. The juice powder contained 40 to 100% of the RDA for 10 micronutrients, including iron, vitamin A and iodine. The researchers observed a statistically significant increase in serum retinol and iron status. In addition, it was shown that younger children also exhibited significant differences in physical growth. These results are, however, difficult to confirm since only an abstract was read and there was no indication of how long the randomized trial was conducted, as well as the number of children included.

Other studies that employed fortification as a strategy fortified with single micronutrients, namely: iron, vitamin A, folate, iodine and zinc. Fortification with iron will be discussed below as an example of a single micronutrient strategy.

The fortification of food items with iron has drawn a lot of controversy since it was discovered that there are individuals within the same community with iron deficiency who also suffer from iron overload (Nesamvuni, 1995 Masters thesis). South Africa with observed incidences of iron overload have delayed their decision to fortify due to the fear that it might exacerbate the condition of those that are likely to be overloaded with iron.

Osler, Milman and Heitmann (1999) studied the consequences of removing iron fortification of flour in Denmark. Denmark was one of the success stories of fortification in the developed world. Mandatory fortification of flour with iron was started in 1954 and was stopped in 1987. Osler and co-workers (1999) found that the mandatory fortification supplied an average of 25% of total iron intake and if it was not implemented 35% of men and 73% of women might have had an inadequate intake of iron during that period. The decision to stop the fortification was approved by the researchers since the iron status of the population continued to improve after the fortification was stopped. The decision was made after considering those at risk of developing chronic diseases due to the effect of additional iron. Thambypillai & Staehr-Johansen (1990) concluded that there is inappropriate use of iron in pregnancy, based on of the evidence of adverse effects of increasing iron stores. They recommended that the use of iron, especially during pregnancy, (in Denmark), be reconsidered.

Children and infants, however, can be provided with iron without any fear of overloading them since it is unknown for children to suffer from iron overload. Dallman (1990) in his review suggested that the success of food fortification and other intervention strategies in infants was due to a better understanding of iron nutrition. A combination of approaches recommended includes the maintenance of breast-feeding and the use of iron fortified infant formula and cereals.

2.6.2.4 *Supplementation*

2.6.2.4.1 *The concepts and needs*

Micronutrient supplementation can simply be defined as the provision of micronutrients taken orally or by injection. It is also referred to as medicinal supplementation. Food supplementation refers to the addition of nutritious foods to a simple diet. A good example is the addition of powdered whole milk or skimmed milk to maize porridge to improve the protein content of the meal. This discussion will focus on micronutrient supplementation (Latham, 1997).

Of the four intervention strategies, supplementation is the one that is regarded as the least sustainable and its major role, therefore, is in short-term intervention. It is only used on long-term basis when capsules with micronutrients are provided to individuals at special risk of the deficiency. The reason for its low sustainability rating is due to the fact that it depends on complex delivery systems that should reach almost all persons at risk of the deficiency, and secondly, on active participation. These two components are rarely realized (Latham, 1997).

The FAO suggested a set of 11 questions that need to be answered in order to seek justification to introduce supplementation (FAO, 1997):

- (i) Is there any population subgroups for which supplementation may be required as short-term assistance? Which? Why?
- (ii) How well designated are these subgroups?
- (iii) What are their specific needs? Have those needs been measured or is it presumed that they exist?
- (iv) Are we sure that the problem is so acute and urgent that supplementation would be appropriate?
- (v) Are we sure that we can match the acuteness and urgency requirements with appropriately massive and prompt interventions?

- (vi) Where would we get the necessary supplies? How will they be delivered? How will they be distributed? How would we ensure that the target population gets them?
- (vii) Is there sufficient support from authorities to ensure the success of the operation?
- (viii) Are proposed beneficiaries aware of the problem? What are the likely attitudes to the proposed assistance?
- (ix) Are we confident that the assistance would continue for as long as needed?
- (x) What parallel measures are we introducing to reduce the period over which supplementation would be needed? Will we be creating an ongoing expectation for the supplements? Has an end point to supplementation been defined and accepted by authorities?
- (xi) How can we ensure that supplementation does not prove counterproductive by giving the false impression that the basic cause of micronutrient deficiencies are being tackled satisfactorily?

Answers to these questions will provide the basis upon which to decide whether supplementation will be the appropriate strategy to implement or not. The answers will allow the initiator to prejudge the success of the strategy before embarking on it. In many instances these questions are not asked, resulting in the failure of the programme, mainly due to its inappropriateness (FAO, 1997).

Supplementation has been implemented in many instances as a choice strategy in many countries. The successes and failures will now be briefly discussed. The supplementations were done for different micronutrients.

2.6.2.4.2. The effect of supplementation on morbidity

In a randomized control trial done in India over a period of one year, the impact of high doses (200 000IU) of vitamin A on morbidity was assessed in mild to moderately malnourished children, aged < 5 years. After comparing for incidences of respiratory illness and diarrhoea between the groups that received supplements with the group that received a placebo, the results as illustrated in Table 2.11 were found:

Table 2.11 Mean number of episodes per child of respiratory illness and diarrhoea after one year of placebo-control trial (Ramakrishnan *et al.*, 1995)

	<i>Vitamin A supplementation</i>	<i>Placebo</i>
<i>Respiratory illness</i>	2.62 (2.95)	2.56 (\pm 2.50)
<i>Diarrhoea</i>	1.90 (2.95)	1.77 (\pm 1.77)

Interestingly, the placebo group exhibited less episodes of morbidity, but the differences in the episodes of morbidity were not statistically significant. This indicated the lack of effect of vitamin A supplementation on common morbidity in areas where access to health care and immunization is good (Ramakrishnan *et al.*, 1995). Contrasting results were shown by Lie *et al.* (1993), who conducted a similar study in the Northern Hebei Province of China. They found that supplementation with high doses of vitamin A decreased the incidence and severity of diarrhoea and respiratory disease. They attributed the impact to enhanced activity on the immune system. In another study in India, Rahmathullah *et al.*, (1991) studied 15 419 children aged 6 to 60 months of which 72% were undernourished and 11% was suffering from xerophthalmia. In this random control trial, half the children received a weekly dose of 2500 micrograms(μ g) of vitamin A, together with 20milligrams(mg) of vitamin E and the other half just 46 μ mol of vitamin E. The weekly low doses of vitamin A

supplement did not have any significant effect on the severity, incidence, and duration of diarrhoea of respiratory infections over 52 weeks of intervention. This could probably be attributed to the dosage since studies that used high doses seem to yield positive results (Rahmathullah *et al.*, 1991).

In South Africa, a similar study was conducted assessing the impact of vitamin A supplementation on measles morbidity (Coutsoudis *et al.*, 1991). In this study 60 children hospitalised with complicated measles, either received the WHO dosage of vitamin A or a placebo. The children were assessed for morbidity (diarrhoea, herpes and respiratory tract infections) at day eight, six weeks and six months. The supplemented group exhibited a reduction of the morbidity score by 82% at day eight, 61% at 6 weeks and 85% at 6 months. At 6 weeks the supplemented group also experienced a significant gain in weight (Coutsoudis *et al.*, 1991). This confirmed the need for vitamin A supplementation in children with measles. The study also received a lot of criticism in relation to ethics because during the time of the study there was irrefutable evidence that withholding vitamin A to children with measles would surely increase the mortality of the children.

Ramakrishnan and Martorell (1998), in their update, concluded that vitamin A supplementation reduces the overall mortality by 23%, mainly through reductions in deaths due to acute gastroenteritis and measles but not acute respiratory infections and malaria. They also questioned whether there is a benefit for supplementation to infants since most studies were done in children above 6 months. One of the controversial conclusions was that “vitamin A supplementation does not reduce overall incidence of common childhood illnesses, however, it reduces the incidence of more severe episodes of diarrhoea”, nor does the supplementation improve the symptomatology of the illness (Ramakrishnan and Martorell, 1998).

Zinc supplementation was also found to have a positive impact on the duration and severity of diarrhoea disease. Sazawal and co-workers (1995) conducted a randomized control trial involving 937 children aged between six and thirty five months in New Delhi, India. There was a 23% reduction in the risk of continued

diarrhoea and a decrease of 39 % in the mean number of watery stools; there was also a 21% decrease in the number of days with watery diarrhoea in children that received zinc supplementation. Regarding the timing of supplementation, if the supplementation is initiated within 3 days of the onset of diarrhoea, “there was a 39 % reduction in the proportion of episodes lasting more than 7 days” (Sazswal *et al.*, 1995). The researchers also found that the reductions in duration and severity of diarrhoea were higher in children who were stunted compared to those with normal growth.

2.6.2.4.3 The effect of supplementation on growth

The association of vitamin A deficiency with growth (wasting and/stunting) has been long established (Brink *et al.*, 1979; Cohen *et al.*, 1983 and Nestel *et al.*, 1993). Many studies were conducted to establish whether supplementing with vitamin A will result in the improvement in growth. Contrasting results were found.

One such study was done in the Sudan (Fawzi *et al.*, 1997) where 28 740 children aged six to 72 months were provided with a six monthly supplementation of vitamin A (200 000IU) for a period of 18 months. At baseline 36% of these children were stunted and 5.6% were wasted. It was found that doses of vitamin A at six months interval did not show consistent appreciable effects on ponderal or linear growth over the intervention period of 18 months. Interestingly enough, 5.8% of the children that were well nourished at baseline and received vitamin A, became stunted over the intervention period. The only positive outcome was observed in girls aged one to three years who gained weight during the study period. Bahl *et al.* (1997) also found an improvement in weight gain of 149g in children who received vitamin A supplementation in the summer season. He concluded that there was a seasonal variation in the impact of the intervention. This obviously needs further research.

The same outcome was observed in two other studies. The first is a study by Kirkwood *et al.* (1996) who supplemented 1500 children with vitamin A. They

also found no significant gain in height and mid-upper arm circumference after 52 weeks of follow up. Contrary to Fawzi *et al.* (1997) children aged 36 months and older who received vitamin A supplementation gained 3g less weight compared to the control group. This difference, though statistically significant, was of no functional consequence especially at this age of rapid growth. The second is the study by Soemantri *et al.* (1997), who studied 144 Indonesian children and found that daily and weekly iron supplementation showed no significant difference in increasing haemoglobin and physical growth.

Other researchers (Angeles *et al.*, 1993) conducted a similar study on 39 children where the experimental group received 30mg of iron with 20mg vitamin C only as compared to the 20mg of vitamin C that the control group received (the follow up was also 12 months). These researchers found that the experimental group showed an increase in height-for-age Z scores which were significantly greater ($p = 0.001$) than those of the control group. They concluded that the increase in height was mainly due to decreased morbidity.

One other study that yielded positive results in terms of growth and vitamin A supplementation was the study by West *et al.* (1997) who conducted a field study on 3377 Nepalese children aged 12 to 60 months, who received 60 000 Retinol Equivalents (RE). The control children received 300RE. They also found no difference in weight and length gain, but a different picture emerged when they concentrated on the children that had xerophthalmia. Xerophthalmic children who were treated with vitamin A, who were not wasted at baseline, gained ~ 0.7centimetres (cm) more in linear growth than non-xerophthalmic children. Xerophthalmic children who were wasted at baseline, gained 672g in weight and ~1cm in height as compared to non-xerophthalmic children. This might indicate that severe vitamin A deficiency has a marked effect on growth and is likely to respond to vitamin A supplementation. These controversial results may be because all the other studies looked at mildly vitamin A deficient children. This was confirmed in a study by Thu *et al.* (1999) who, after selecting stunted children who were part of a bigger study in Vietnam, found that the height-for-age increased with Z scores of 0.48 ($p < 0.001$) and 0.37 ($p < 0.001$) for daily and weekly supplementation, respectively. This was despite

the fact that they also found no effect on growth in the overall population. It could be assumed that those children that were stunted at baseline might have had a more severe form of vitamin A deficiency.

Children that are infected with Human Immuno Virus (HIV) also seem to receive a positive outcome from vitamin A supplementation. In a randomized clinical trial among 687 children, Villamor *et al.*, (2002) gave an oral dose of 200 000 International Units (IU) to the experimental group and a placebo to the control group. Of these children 24% and 9% were found to be infected with malaria and HIV respectively. Children who were infected with HIV gained a significant length increase (2.8 cm) after 4 months of vitamin A intervention in comparison to those that received a placebo. This gain in height was not observed in the HIV negative children. Similarly, children with malaria experienced a 747g gain in weight, which was attributed to vitamin A supplementation. The improvements in weight gain were not experienced in children without malaria. "The risk of stunting associated with episodes of diarrhoea during follow-up was virtually eliminated by vitamin A supplements" (Villamor *et al.*, 2002). These researchers concluded that supplementation with vitamin A improved both linear and ponderal growth and reduced the risk of stunting associated with persistent diarrhoea in children infected with HIV and malaria. This confirms the above study by Thu *et al.*: (1999) that vitamin A supplementation is more effective in more severe cases of vitamin A deficiency, since it is possible that both malaria and HIV will ensure severely depleted vitamin A stores (Villamor *et al.*, 2002).

In summary, it is evident that though the link between growth and micronutrients has long been established, it remains a mystery why scientific research has not yielded any convincing results to confirm this link. Allen (1994) suggested that it could be due to the fact that growth is limited by multiple, simultaneous deficiencies in many populations. It remains to be seen whether supplementation with several micronutrients at one time will have any positive results. The IVACG symposium held in Hanoi Vietnam (2001) announced that almost a million deaths were averted since 1998 through the distribution of high dose vitamin A capsules. This is quite impressive and it

confirms that there is still a place for vitamin A supplementation, even though the impact on growth is not found to be significant.

2.6.3 Public health measures

Public health measures or actions are regarded as the second most sustainable intervention strategy for combating micronutrient deficiencies (Latham, 1997).

The following measures could be implemented:

- Early diagnosis.
- Reduction of malnutrition.
 - Good maternal child health services
 - Family planning
 - Environmental and hygiene measures
- Reductions of infections
 - De-worming
- Immunisation
- Reduction in transmission of parasitic infection
- Sanitation.

All of these measures are part of primary health care services that can be introduced in any region. When deficiencies are diagnosed early, proper treatment can be implemented early and, therefore, prevent severe deficiencies. It is also obvious that measures that reduce infections and promote good health will help in reducing micronutrient deficiencies (Latham, 1997).

This means that health care workers in primary health care services should be trained to be quick in recognising children who are showing signs of nutritional deficiency as well as signs of infections. It is, however, also important that after a correct diagnosis the workers should be able to provide appropriate treatment. Mothers are also required to be educated on the importance of immunisation as well as to seek early health treatment at the primary health care centres. This

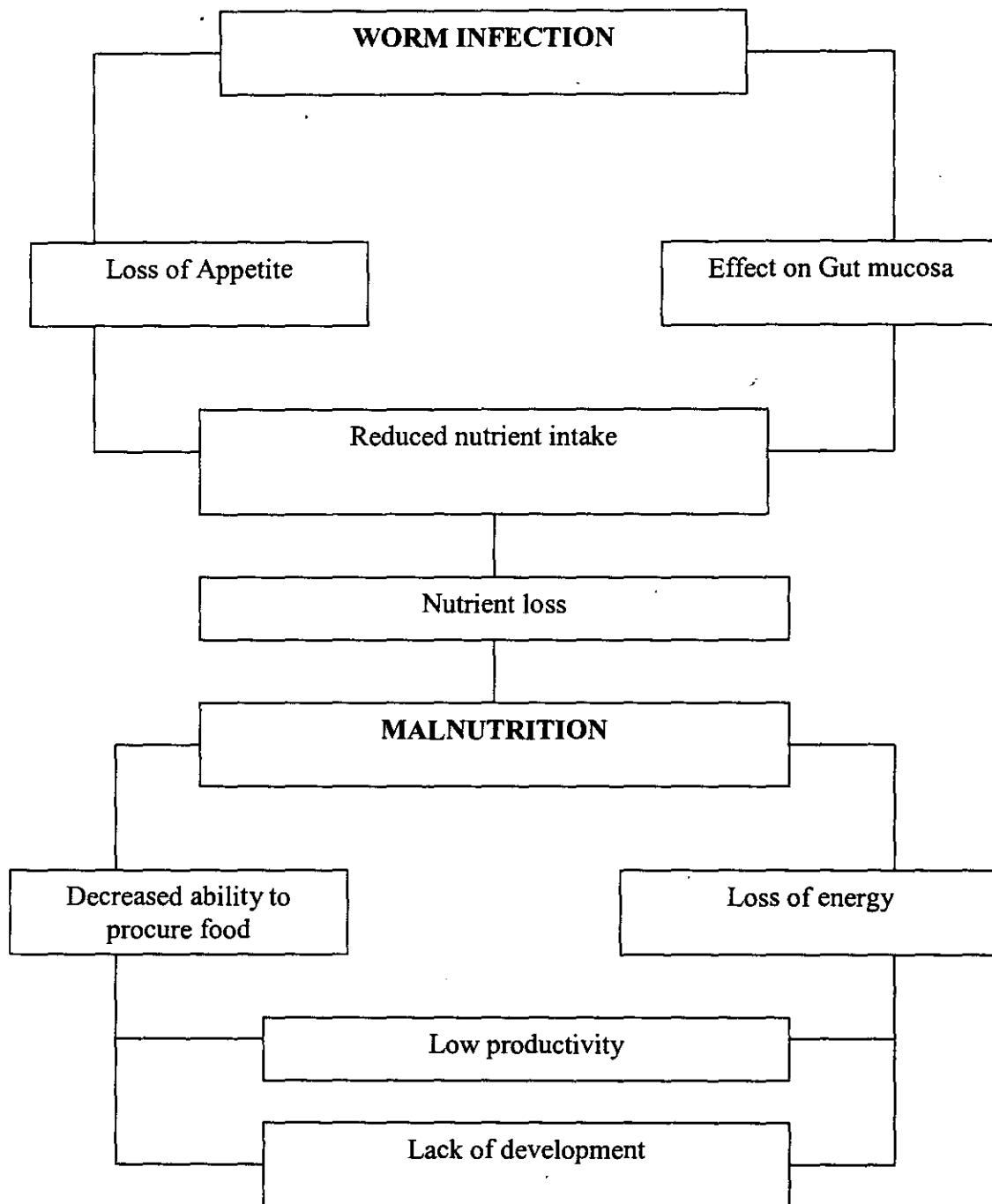
means, therefore, that these centres should be “mother friendly”. The health workers in these centres play a major role in this.

UNICEF (1996) reported about a unique and successful public health measure in Niger. It was noted that after the women in the Muyahi region joined the Nutrition, Family Food Security and Environmental Programme, child malnutrition decreased by 18% and infant deaths went down from 160 to 123 per 1000 live births. Their workload decreased by two hours per day which resulted in the extension of exclusive breast feeding from four to five months on average. The reduction in workload was as a result of the use of motorised mills as well as donated mule carts to transport water. Most importantly, the women attended literacy programmes and they also learnt how to monitor the children’s growth.

In Cameroon the training of primary school teachers about nutrition, vitamin A deficiency, its causes and prevention and management, coupled with school visits and vitamin A supplementation, resulted in 80% recovery rate of sight in those children already suffering from vitamin A deficiency diseases (Namanga, 2001).

With iron deficiency, a public health measure of great importance is the control of worm infestation. The interaction of worm infestation and the development of malnutrition are shown in Figure 2.2 below.

In a study by Awasthi and Pande (2001), done in the urban slums of North India, it was found that six monthly de-worming with Aldendazole resulted in underweight children showing a significant improvement ($p = 0.043$) in weight. Gopaldas (1996) also reported significant and highly cost-effective and sustainable improvements in growth rates and haemoglobin levels, and decreases in the prevalence of ocular signs of vitamin A deficiency. This was after 3 million children in Gujarat were given a daily free meal with Albendazole.



* adapted from Latham, (1997)

Figure 2.2: Worm infestation and malnutrition*

Hookworm infestation was found to be the strongest predictor of iron deficiency. It was found of the Nepalese women who took part in a study by Dreyfuss *et al.* (2000), 72.6 % were anaemic, 74.2% had hookworm infestation and 19.8% tested positive for malaria parasitaemia. It was then recommended that programmes designed for iron intervention should also consider other adverse factors like worm infestation and malaria infection.

It is, therefore, very evident that these measures, though effective to reduce micronutrient deficiency, also have a great impact on the effectiveness of other programmes like fortification and supplementation. It is actually advisable that supplementation programmes are implemented, coupled with a public health measure, in order to improve its effectiveness.

2.6.4 Dietary diversification

The ultimate goal in the attainment of food and nutrient security is to ensure that communities consume a variety of foods, which will provide required quality and quantity of micronutrients essential for health (Latham, 1997). This is the most sustainable and long term strategy of combating malnutrition as well as micronutrient deficiency.

Nutrition education will play a role in this strategy, but only if the appropriate foods are available. Therefore, there has to be a comprehensive stimulation of the production of and consumption of nutrient rich foods (Latham, 1997). Communities that exhibit high prevalence of vitamin A deficiency would, specifically, be encouraged to consume foods high in beta-carotene. Those communities with iron deficiency will be encouraged to consume foods of animal origin even if they are in small amounts as well as the inclusion of vitamin C rich foods, to promote the absorption of non-haeme Iron (Monsen, 1988; Bothwell *et al.*, 1989; Cook *et al.*, 1991).

The other general recommendation is the promotion of the consumption of green leafy vegetables, which are both rich in iron and vitamin A (Latham, 1997).

It is evident that for this approach to be successful, there has to be cooperation between the agricultural sector, school based programmes and the community and that household food insecurity should be addressed.

2.6.5 Successful dietary diversification

International Vitamin A Consultative Group (IVACG) (2001) reported on a successful programme in Vietnam which resulted in the reduction of PEM from 52% in 1980 to 34% in 2000. This was achieved through a combination of supplementation and the VAC (garden, water and animal husbandry) farming method. The farming method was introduced to promote the production of food with emphasis on food rich in vitamin A. This method improved household food security and the intake of foods rich in vitamin A. The prevalence of low serum retinol ($<0.7\mu\text{mol/l}$) improved as follows:

20 – 30 %	<12months
10.5% after	12 – 24 months
5.3% after	24 – 36 months
11.7% after	36 – 48 months
6.3% after	48 – 60 months

The consumption of animal foods increased from 34 to 91g/capita/day from 1980's to 1990's.

In summary, for vitamin A deficiency dietary diversification is the preferred form of intervention in deficient countries. It is suggested that it starts together with supplementation. Support from agricultural extension is necessary (World Bank, 1994). This method is not recommended for iodine deficiency since it has been found to be ineffective in reversing iodine deficiency (Latham, 1997; World Bank, 1994). With regards to iron, dietary diversification is effective

where meat is consumed widely, it is also necessary that the production of livestock be promoted at small to medium scale through agricultural extension. Legumes and vitamin C are also useful (World Bank, 1994; Latham, 1997).

2.7 SUMMARY AND MOTIVATION

The above review clearly indicated that micronutrient deficiencies are global problems, especially in children. It showed that these deficiencies often occur in children with PEM with devastating immediate and long term consequences. The review also showed that the causes of undernutrition in children are complex and interrelated, and that to address these causes, holistic, multisectorial strategies and programmes are needed. One of strategies is food fortification.

In South Africa, the National Department of Health is in a process of implementing mandatory food fortification of staples such as maize and bread flour. It is, therefore, important to assess if micronutrient fortification of these staples will indeed have beneficial effects on the nutritional status and growth of malnourished children.

These facts motivated the present study, in which the effects of fortified maize meal on the anthropometric and biochemical nutritional status of malnourished African children residing in Oukasie, Brits have been examined.

CHAPTER 3: METHODOLOGY

3.1 INTRODUCTION

General methodology and details of the methods used in this study are discussed in this chapter. The study design used was a parallel, case-controlled intervention trial in which the effectiveness of vitamin A fortification of maize was analysed.

Several variables indicative of nutritional status of 1 – 3 years old African Children living in Oukasie, Brits were measured at baseline and end including:

- Anthropometric measurements
- Biochemical analysis
- Blood haemoglobin and haematocrit
- Serum retinol and retinol binding protein
- Factors influencing child care
- Nutritional knowledge of the caregivers
- Dietary intakes of the children.

The last three aspects were covered as sub-studies by other researchers (master's students). Unfortunately the researcher responsible for the dietary intakes dropped out before completing the study. The factors influencing child care and nutritional knowledge of mothers and caregivers were studied for a master's degree with the Medical University of Southern Africa. The student was Pauline Tladinyane [Bachelor of Science in dietetics (UWC)]. The biochemical analyses (retinol and retinol binding protein) were carried out in the Institute of Pathology of the University of Pretoria. The anthropometry and haematological analyses (haemoglobin and haematocrit) were done immediately on site of blood collection by the researcher and assistants.

3.2 OBJECTIVES OF THE STUDY

3.2.1 *Baseline information of the study population*

The objectives of this part of the study were to obtain baseline information of the study population, including:

- Socio-demographic data;
- Nutritional status (anthropometry and biochemistry).
- Nutritional knowledge of the mothers and care givers.

3.2.2 *Intervention programme*

- The objectives of this part of the study were to design and implement an intervention programme to evaluate the effectiveness of fortified maize meal to address under-nutrition by:
 - Selecting 60 stunted or underweight children of whom 30 were randomly allocated to the experimental group and the remaining 30 allocated to the control group (because of unavoidable circumstances, measurements of only 44 children were available at baseline).
 - Providing fortified maize meal to the experimental group and unfortified maize meal to the control group and their families for at least One year, to replace all maize meal habitually consumed in the respective households
 - Assessing anthropometric and biochemical nutritional status of the experimental and control group after one year of intervention.

3.3 STUDY DESIGN AND IMPLEMENTATION

3.3.2 *Schematic representation of the design*

The major objective of this epidemiological, intervention study was to assess the relationship between environmental exposures and nutritional outcomes at baseline and after fortified maize has been consumed by an experimental group of children for at least a year compared to a control group of children who received unfortified maize meal. To accomplish this, the following design illustrated in **Figure 3.1** was used:

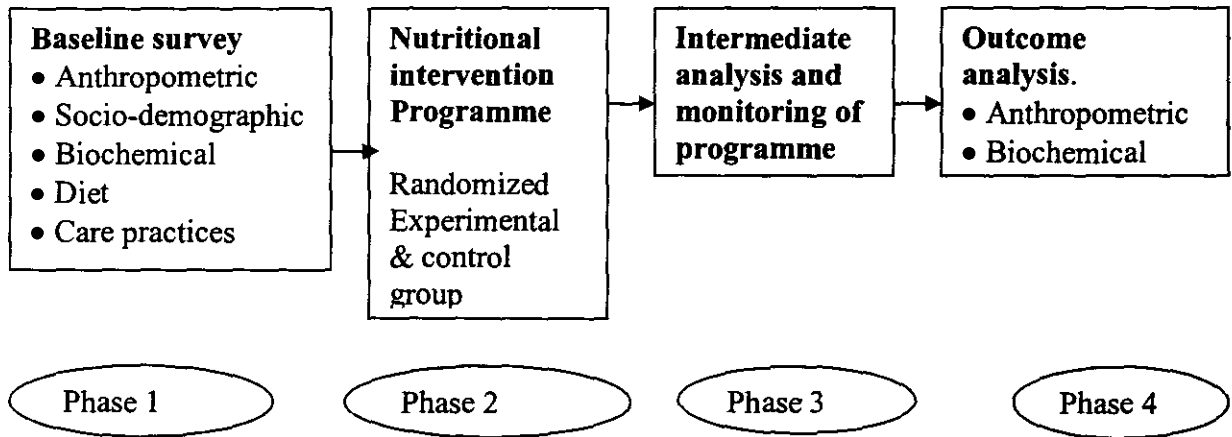


Fig 3.1 *Schematic presentation of the study design.*

The above design was planned to be followed for this study. However, after medical advice, it was suggested that the 3rd phase, the intermediate analysis, be removed since the children from whom the blood was to be collected were very young to endure the trauma of 3 blood samplings within one year. The baseline was done on the 8th and 9th of August 1999 and the intervention began in September 1999 until the end of September 2000. The outcome analyses were conducted on the 9th and 10th of October 2000.

3.3.2 Study type and setting

- **Type.** This study was a randomised parallel case-control intervention study in which families of experimental children received fortified maize meal and those of the control group, unfortified maize meal. Therefore, both groups received the maize meal intervention, but the experimental children also the additional micronutrients (vitamins) provided by the fortified maize meal.

- **Setting:** Oukasie is a formal settlement situated 2km East of Brits in the North West Province. It was established in 1928 and it has deep political history. It was deemed as an illegal settlement from its establishment until 1991. The area is comprised of formal and informal houses, RDP houses and squatter camps. It is fully serviced by the Brits City Council in terms of water, sewage and emergency services. It has one clinic, one formal crèche, two primary schools and one secondary school.

3.3.3 Period and duration

The study started in 1999 and ended in September 2000. The collection of data was done from August 1999 and was completed in September 2000. The actual intervention including fieldworker training and organisational procedures in the community, took 13 months.

3.3.4 Fieldworkers

The fieldworkers were recruited from the community of Oukasie. An advertisement notice was placed at the Oukasie Development Trust (ODT) where the community pays for their services. The requirements were as follows

- Minimum of Grade 10 qualification
- Female
- Setswana Speaking

The reason for opting for females was the fact that they are easily acceptable when entering a household. Most, if not all, the caregivers of the participating children were female. They have an inherent understanding of children and caring for the child. After a lengthy screening process, ten fieldworkers were appointed. It was important that a democratic process was followed to ensure the acceptability of the fieldworkers, and for the community to realise the seriousness of the project.

The fieldworkers were remunerated at R90 for a full work day, which sometimes included evenings if mothers were working during the day.

The training of the fieldworkers took place first in 1997 with a workshop conducted by two experienced fieldworkers from the Transition and Health during Urbanisation of South African (THUSA), study then again in 1998 when the fieldworkers were being trained for the National Food Consumption survey. The second training was conducted by Dr U MacIntyre of Medical University of Southern Africa (Medunsa).

The fieldworkers helped with the completion of all questionnaires and ensured that the participating families received the correct maize meal in time. They therefore also assisted in monitoring compliance to the intervention.

3.4 ETHICAL CONSIDERATIONS

The study was approved by the Ethics Committee of the University of Potchefstroom for Christian Higher Education (Ethics # VGE 7M8/98). Consent from leaders of the community was also obtained. Informed consent was obtained from mothers/caregivers (Appendix 1). Subjects participated willingly and were allowed to withdraw from the study at any time. The participants were guaranteed confidentiality and privacy. Feedback will be provided to the Oukasie community as soon the report is final.

3.5 SAMPLE SELECTION

3.5.1 *Sampling method*

The study sample comprised of 60 children aged one to three years who were found to be stunted or underweight, applying the NCHS criteria. For inclusion in the study the children had to have height-for-age or weight-for-age below the 5th percentile. The children were selected from the Oukasie clinic and three creche's within Oukasie. All the children in the age group one to three years were screened until a sample of 60 children was attained with parental/guardian consent.

3.5.2 *Sample size*

Because of the small variations between subjects in measured variables (see baseline values in all tables in Chapter 4) a sample size of 60 children was estimated to be sufficient in terms of power and level of statistical significance; at 80% and 5 % respectively to show significant changes in outcomes variables after the intervention.

However, after baseline blood collection the sample size reduced from 30 in each group to 25 children for the experimental group and 24 children for the control group. This was because the nurse could not get any blood from 11 children. The veins of children this age are difficult to locate. In some children only enough blood to analyse haematological parameters was collected. Eventually full data at baseline were available for 21 children in the experimental group and 23 in the control group. In five children the blood that was collected was not enough to do all the haematological and biochemical analysis. At the end of the study only 16 and 20 children in the respective groups were available for measurement. This reduction in sample size resulted in a negative impact on the power and level of statistical significance. As indicated earlier, a sample size of 30 children per group was sufficient for the

power and level of significance. The impact of this reduced sample size will be discussed in detail in Chapter 5.

3.5.3 Exclusion criteria

The study excluded:

- Children with physical or mental disability
- Children with severe forms of PEM, namely kwashiorkor and marasmus
- Children of mothers who have recently relocated to the study area.

According to these criteria those children who were on the PEM programme and on the register for disabled children in the clinic were excluded.

From anecdotal observation of the children at baseline and end, the children exhibited no clinical signs associated with HIV/Acquired Immune Deficiency Syndrome (AIDS) infection. No blood tests were conducted to confirm the absence of the infection. It is, therefore, assumed that in large the children were HIV negative during the time of the study.

3.6 THE FORTIFICATION OF MAIZE

The technology to fortify flour was described by the Opportunities for Micronutrient Intervention (OMNI, 1997).

Maize flour fortification is done by using a premix. The advantage of using a premix is that there is a greater likelihood of ensuring:

- The correct concentration of micronutrients
- An even distribution of micronutrients.

The logistics of adding micronutrients to the flour is simpler and the quality assurance system is more likely to be effective. The fortification process itself is accomplished by adding the micronutrients through a volumetric feeder located towards the end of the milling process. The feeder consists of a rotating feed screw that is driven by a variable speed motor. The feed screw rotates inside a chamber containing the premix and pushes the premix through an outlet spout. The quantity of the premix added can be modified by changing the motor speed. The concentration of the premix added can be calculated by weighing the amount of premix deposited by the feeder in one minute divided by the volume of flow passing underneath in the same period of time. The premix can either be fed directly into the maize by gravity or using a pneumatic system. The homogeneity of micronutrients in fortified flour is largely dependent on the location of the feeder and it is important that the flour is thoroughly mixed. In a gravity driven system, experience has shown that the best site for adding micronutrients is before the mid point along the screw conveyor that collects the flour from all the mill passages, just before sacking.

If the feeder is placed towards the beginning of the screw conveyor, the amount of flour in the conveyor will be too little and if the feeder is at the end the required homogenisation will not be achieved. Vitamins are less stable as compared to minerals and they can be affected by heat, oxidising and reducing agents, light and humidity. It is advised that the use of encapsulated forms of vitamin A be used to reduce the losses that can occur during storage.

In this study the Vitamin division of Roche Products (Property) Limited (Isando South Africa) prepared the premix for the maize meal to 100% of RDA for children aged 1 – 3 years. The exact levels of fortification are depicted in Table 3.1. The premix was sent to Maizecor, a milling company where the premix was added into the maize meal using the process described earlier.

3.7 INTERVENTION PROTOCOL: DISTRIBUTION OF THE MAIZE MEAL

The maize was estimated to have a shelf life of ~four months, therefore, the maize meal was delivered to the Oukasie Community Hall three times for the year of intervention, in three monthly batches. Each batch was randomly tested for the accuracy of the fortification. The maize was stored in the storeroom of the Oukasie Community Hall, which was regarded to be fit for maize storage by the Mill Manager, Mr. Maloka.

The maize meal was packed in identical quantities of 25kilograms(kg) white bags with the fortified maize closed with a yellow thread and the placebo with a white thread. Only the researcher knew what the maize meal contained.

The maize meal was distributed from the hall by the fieldworkers. Each fieldworker had her own participating families whom she distributed the maize meal to. All she knew was the colour thread on the bag the family should get.

When the maize meal was nearly finished the mother or caregiver approached the fieldworker and they collected the ration of maize from the community hall. The ration varied from 25 to 50kg depending on the number of people living in the household. The researcher visited the distribution point on a monthly basis to ensure that the correct maize was distributed. After the first distribution the mother/caregiver also knew the colour thread of the maize meal she should receive.

3.8 MONITORING THE INTERVENTION

3.8.1 Fortification levels and Distribution of maize and testing of vitamin A content

A single blind “placebo” – controlled trial was done over a period of one year from September 1999 to September 2000. All the subjects and the fieldworkers

were “blinded” to the treatment and received anonymous intervention in that they knew that the maize meal was the intervention product but did not know what it contained. Anecdotal information from the subjects and fieldworkers indicated that the vitamin fortified maize meal was indistinguishable in colour and smell from the non-fortified maize meal (placebo), no sensory evaluation was done. A premix with the vitamins was produced by Roche Products (Pty) Ltd. The premix is produced by mixing maize meal and retinyl palmitate in a V type blender. The preparation of the premix was based on 100% RDA for vitamin A, thiamine, riboflavin and pyridoxine, for children aged between one to three years which is 1700IU. It was estimated that each child would consume on average ~150g of dry maize meal per day. The content of the premix was verified for accuracy before it was sent to the maize refinery for fortification. The results are as follows:

Table 3.1 *Declared and tested vitamin content of the premix used to fortify the maize meal for the study*

Reference # F99-072

Batch number	Analysed for	Declared levels	Results found per 15 mg	Unfortified
Lot 3 (August 99)	vitamin A Palm	1700IU/150g	1786IU/150g	0IU/150g
	Thiamine	0.61mg/150g	0.69mg/150g	
	Riboflavin	0.62mg/150g	0.64mg150g	
	Pyridoxine	0.56mg/150g	0.62mg150g	

Before the maize meal was distributed, the vitamin A content of the different batches of fortified maize were analysed and verified by Roche Products (Pty) Ltd. The fortified maize meal was declared to contain 1700IU/150g and the unfortified maize meal 0IU/150g (Table 3.1).

The content of vitamin A varied from one batch to the other but it was never lower than the declared level.

3.8.2 Retention of vitamin A after cooking

The maize was further tested for retention of the added vitamin A after the cooking process. To do this, two mothers from the study area were taken to Roche laboratories in Isando to show the technician the cooking process used to prepare the maize meal by the community. Two methods were used and are described as follows:

- ***Cooking process one***

1500 millilitres (ml) of water and 2g of salt are brought to the boil. 500g of maize meal is added gradually with the aid of a whisk to prevent the formation of lumps. Once all the maize meal is mixed in, the heat is reduced to medium and the maize meal is left to simmer with the lid on for 30 minutes with occasional stirring.

- ***Cooking process two***

Weigh 336g maize meal

Weigh 750 ml of water into a pot and bring to a boil

Add maize meal and stir the mix with a fork. Close the pot by putting the lid on.

Lower the heat and let the porridge steam cook for 30 minutes.

The outcome of this monitoring indicated that when cooking process one is used 71% (1207mg/150g) of vitamin A was retained and when cooking process two was used only 55% (935mg/150g) of vitamin A was retained.

This means that the experimental group consumed ~935 – 1207mg/150g dry weight of vitamin A extra compared to the control group.

3.9 EXPERIMENTAL METHODS

3.9.1 *Introduction*

The face to face interviews used in this study were usually preferred in cases where the educational level was not optimal. The advantages of this option are: low burden to the respondent and, therefore, good acceptance by the subject. It also saves time, has a higher validity and it can be standardised (Dwyer, 1994).

Two questionnaires were used, one for collecting socio-demographic data and another for child care and nutritional knowledge of the mothers and caregivers. Anthropometric measurements, i.e. height and weight of the children, were taken and recorded on a form designed for this purpose.

3.9.2 *Socio demographic questionnaire*

The questionnaire used for this purpose was adapted from the one developed and validated for the national food consumption survey (**Appendix 2**). The questionnaire asked questions related to the following:

- Child's gender, age, religion and ethnic group
- Marital status of the mother
- Type of housing
- Availability of water and other sanitary facilities
- Sources of fuel
- Availability of working electrical appliances
- Employment status of the mother and father
- Household income
- Amount of money spent on food.

3.9.3 *Child care and nutritional knowledge questionnaire*

For this purpose another researcher developed a coded and structured questionnaire to obtain information related to child care practices and nutritional knowledge (**Appendix 3**).

The questionnaire asked questions related to the following:

- Educational knowledge
- Family Support
- Control of family resources
- Workload
- Hygiene practices

- Nutritional knowledge on:
 - Initiation of breast feeding
 - Duration of breastfeeding
 - Introduction of complementary foods.
 - Frequency of feeding and
 - Adequacy of complementary foods.

3.9.4 *Validity and reliability of questionnaires for this study*

Validity is the degree to which a measuring tool reflects the true value of the desired outcome without contamination (Dunn, 1989).

For the two questionnaires used in this study, face validity was used to validate the questionnaires. This type of validity testing relies basically on the subjective judgment of the researcher. It asks if the instrument is measuring what it is supposed to measure and if the sample measured is representative of the behaviour or trait being measured. The researcher finally decides in accordance to his/her best judgement (Leedy, 1997).

Reliability refers to how well the tool constantly yields similar results (Leedy, 1997, Margetts and Nelson, 1997). If a measure is not reliable, it reduces its validity (Abramson, 1994) and the possibility of correctly identifying casual relationships is reduced (Margetts & Nelson, 1997). In this study the test-retest method was used to establish reliability. This method compares the results of two administrations of the same measuring tool separated by some time interval (Leedy, 1997).

The researcher who developed the child care and nutritional knowledge questionnaire re-interviewed five subjects from each group to establish reliability of the questionnaire after 1 week.

3.9.5 *Anthropometric measurements*

3.9.5.1 *Weight*

Weight of the children with was measured using a “Clover” electronic scale while they wore only minimal clothing (underwear). The scale was standardised every morning by placing a 5 kg weight on the scale. The scale was placed on an even cement area, and the child was required to stand still in the middle of the scale platform without touching anything with the body weight equally distributed on both feet (Lee and Nieman, 1993). The weight was read to the nearest 0.1kg and the average of two measurements taken in immediate succession and recorded on the space provided in the record form (**Appendix 4**).

For children less than two years who were afraid to step on the scale the child was weighed together with the mother, then the mother was weighed alone and the child’s weight was calculated as the difference of the two measurements.

3.9.5.2 *Height*

The standing height of the child was measured to the nearest 0.1 cm using a stadiometer. The child was barefoot and wearing minimal clothing to facilitate correct positioning of the body. The child was expected to stand with heels

together, arms on the side, legs straight, shoulders relaxed and the head in the Frankfort horizontal plane (Lee and Nieman, 1993). The heels, buttocks, scapulae and back of the head were against the vertical board of the stadiometer.

Two measurements were taken and the average was recorded on the space provided on the record form. For children less than two years, recumbent length was measured.

3.9.6 Blood and serum measurements

3.9.6.1 Collection and preparation of blood samples

Blood samples were collected to measure serum vitamin A status, haemoglobin and haematocrit. Trained registered professional nurses, together with two trained assistants were used for drawing of blood from the children. The blood samples were drawn between 08:00 - 13:00 to control for the effect of environmental temperature and circadian rhythms on the level of variables. Sterile disposable syringes and a 23G-butterfly system were used to collect blood from the anterior cubital vein of the child. The blood collected was immediately separated by the two assistants to prepare:

- 1 x 5ml Ethyl diamine tetra-acetic acid (EDTA) blood for the analysis of haematocrit and haemoglobin
- And were possible 2 x 5ml for serum preparation.

The latter samples were then centrifuged at 3000 revolutions per minute for 10 minutes and kept on ice until they were aliquoted into previously marked Ependorff tubes (± 2 /child). In the field the aliquots were immediately placed in a standard freezer (-18 to -22°C) and back in the laboratory, stored at -84°C until they were analysed.

3.9.6.2 Blood haematocrit

Haematocrit was determined in the field laboratory by Dr TA Nell using a haematocrit centrifuge with capillary tubes (Hettich Zentrifugen, haematocrit 24D-78532, Tuttlingen).

3.9.6.3 Blood haemoglobin

Haemoglobin was also determined in the field laboratory by Dr TA Nell using cyanomethaemoglobin colorimetric method from Boehringer Mannheim (Germany).

3.9.6.4 Serum retinol

Serum retinol was analysed by the Institute of Pathology at the University of Pretoria using High Performance Liquid Chromatography (HPLC) methodology.

3.9.6.5 Retinol binding protein

Serum retinol binding protein concentration was determined using the Modified, Relative Dose Response (MRDR) test. This test was also conducted by the Institute of Pathology, University of Pretoria. The normal ranges for these variables for children are indicated in the tables for biochemical variables in Chapter 4.

3.9 STATISTICAL ANALYSIS

All data from the questionnaires were electronically captured in a data file. The computerised data was checked for accuracy and consistency against the original questionnaires and validated.

The statistical analysis was done using the Statistical Package for Social Sciences (version 10) for windows program.

Descriptive statistics were used to determine means, standard deviations, 95% confidence intervals, medians, minimum and maximum values and range.

Changes from baseline to the end of the one year intervention in the experimental group for all variables were compared with those in the control group using paired T-tests, and analyses of variances. Differences were considered to be statistically significant if $P \leq 0.05$. Pearson as well as Spearman correlation coefficients were used to test associations between biochemical and haematological measured variables and also between changes of these variables. Correlations were considered to be significant at a 10% level ($p \leq 0.01$).

Further statistics were done to compensate for expected growth of the children. A weight adjustment of 2.4Kg was done and all statistics were repeated. This is due to the fact that children aged one to three years are physiologically expected to gain ~2.4kg if no intervention is implemented (NCHS, 1977).

T- Tests for between-subjects effect were also conducted.

CHAPTER 4: RESULTS

4.1 INTRODUCTION

In this chapter, the anthropometric (weight and height) as well as the haematological (haemoglobin and haematocrit) and biochemical (retinol and retinol binding protein) data of the experimental and control groups before and after intervention are compared to assess the effect of the fortified maize meal on the nutritional status of the subjects.

The sociodemographic profile, child care practices and dietary patterns of the children are described to illustrate and depict the environment in which the children live. The latter was presented as an MSc Thesis by Pauline Tladinyane at the Medical University of Southern Africa. Comparison of the findings with other studies, as well as the interpretation of the observed results will follow in Chapter 5.

4.2 PROTOCOL LIMITATIONS AND VIOLATIONS

4.2.1 *Sample*

The study was designed to assess the effectiveness of vitamin A fortification of maize on the nutritional status of the children aged one to three years in Oukasie. The study was intended to start in 1997 and to end in 1999. The study did start with 92 selected children but due to logistical problems with the last batch of maize that was delivered it had to be stopped and restarted. It was found that the maize meal was fortified incorrectly and this meant that the control children received fortified maize and that some took in higher amounts of the fortificant for a short period of time. This mishap had the following implications:

- A whole new sample had to be selected since there was “contamination” of subjects: the control subjects also received fortified maize meal and the experimental subjects received incorrectly fortified maize meal.
- A new smaller sample had to be re-selected since the available maize would not cover the initially intended sample of 100 children
- The duration of the study also had to be reduced from 16 months to 12 months for the same reason as the above point.

With the initial study sample selected in 1997, a total of 92 children were selected which was sufficient for observing changes in nutritional status. After a new sample was selected, only 76 suitable children were available, and eventually baseline data for eventually only 44 children who complied to all inclusion criteria were collected. This meant that greater changes in nutritional status needed to be observed for sufficient power, since the duration of the study was also shortened.

Therefore, the results from the smaller sample and the association of variables need to be studied very carefully. This is due to the fact that the effect of chance on associations between variables may be high in a study with small numbers (Margetts and Nelson, 1998). To judge if the results obtained occurred by chance, estimation of confidence intervals was assessed.

The results and the discussion of this thesis concentrate only on the second and much smaller sample, since it was the only group with valid baseline and outcome data.

4.2.2 *Vitamins fortified*

The initial protocol also intended to measure other serum vitamins such as folate, riboflavin, niacin and thiamine. Due to the age of the children, insufficient blood samples were collected for full serum vitamin analysis. Therefore, only serum retinol and retinol binding protein were measured and

used as a marker for changes in vitamin status. The maize meal was fortified with these other vitamins including folic acid, riboflavin, thiamine and vitamin B6.

4.2.3 Selection of children

The choice of selecting children aged one to three years for an intervention and follow-up study that aims to assess nutritional influences on growth might have been a mistake. These children are in an accelerated growth spurt stage. To show differences between experimental and control groups, all receiving sufficient macronutrients, would be difficult over a period of eight months. In hind site the age group that would probably have been ideal would have been primary school children whose growth has slowed down. It could also have been easier to collect sufficient blood from these older children to conduct all the necessary investigation. However, this age group (one to three years) has been shown to be vulnerable regarding their nutritional status since they are often exposed to inappropriate weaning practices (Labadarios *et al.*, 2000).

4.2.4 The research environment

The study was done under free living conditions. The research environment was not controlled in the sense that the researcher had to rely on the narrative report from the families that their children were consuming the maize meal. There was also little control of the diet the children were consuming on a daily basis. This meant that the food the children were eating, in addition to the maize porridge, might have played a role in changing the overall nutritional status. It would have been ideal to choose institutions like a school or a crèche to ensure that the meals the children consume at the institutions (school or crèche) were fortified or unfortified. This would have ensured greater control on the intake. However, not all the children in such an institution would necessarily met all inclusion criteria. Nevertheless, it is, therefore, possible to assess the effect of consuming one meal that contains a fortified food item on the nutritional status of the children under more controlled conditions than what was attempted in this study.

4.2.5 Measuring instruments

In retrospect it was realised that in certain questions of the socio-demographic and nutritional knowledge questionnaires, more options should have been included. With the question on educational status, there should have been an option of “no education” for both caregiver and mother. Another option on the educational level of the mother: a “do not know” should have been included to cater for cases where the caregiver was a respondent and he/she did not know the educational status of the child’s mother.

4.3 SOCIO DEMOGRAPHIC INFORMATION

4.3.1 General information

A total of 60 children who met the criteria were randomly selected from the 79 available children of which only 49 could be used for the trial for anthropometric, haematological and biochemical data collection at baseline. Eleven were excluded because there was insufficient or no blood samples obtainable at baseline. Eventually data for only 44 children at baseline was completed; and only 36 children were available for outcome measurements. However, the socio-demographic information were available for 49 children. The majority of the children were girls (65%). All the children were from different Christian denominations. The ethnic distribution was as follows:

Tswana	57.8%
Pedi	26.1%
Shangaan	4.5%
Venda	3.6%
Ndebele	2.7%
Zulu	1.8%
Coloured	1.8%
Xhosa	1.8%
Sotho	0.9%

Eighty seven percent of the respondents were mothers, and the remaining 12.7% of respondents included fathers, grandparents, aunts/uncles, siblings or an appointed caregiver.

4.3.2 Household composition

The composition of the household was determined by the number of people (both adults and children) living in the household. The majority of the households comprised of 3 to 6 occupants. The percentage of people in the household is presented in Table 4.1.

Table 4.1 *Number of people living and sleeping in the house as percentage of the total*

Number of people	Percentage
1 – 2 people	21.8
3 – 4 people	40.0
5 – 6 people	27.2
7 – 8 people	9.1
> 8 people	1.8

4.3.3 Marital status of the mothers

A mother was regarded as single if she was unmarried, widowed, or if she was not living with a partner. The rationale was to evaluate the presence of emotional support to the mother. The majority (63%) of the mothers were regarded as single, meaning that there was 63% female headed households as compared to 37% who were legally married or were living with their partners.

4.3.4 Responsibility for food preparation and child feeding

Mothers were in the majority (78.2%) when it came to food preparation and feeding the child. The remaining 22.8 % children were fed by grandparents (11%), aunts (8%) and siblings (3.8%).

4.3.5 Type of dwelling and source of fuel used for cooking

A house was regarded as informal if it was built from mud, tin or wood, and those built from bricks and concrete were regarded as formal. A resounding majority of the homes (78%) were informal compared to 22% built from bricks. The informal houses were built from tin or corrugated iron. The most commonly used form of fuel was paraffin (65%) followed by wood/coal (18.2%) and only 16.8% of the households had electricity.

4.3.6 Water supply and sanitation facilities

The assessment of the water supply and availability of sanitation facilities were used as an indicator of the extent of the hygienic environment in which the children were living. It also serves to judge whether the children were exposed to any hygiene and safety hazards that could predispose them to infections, influencing nutritional status.

All the families obtained water from safe sources: 42% from communal taps and 58% from household taps. The type of ablution was classified as either flush or not a flush toilet (bucket and pit). The entire group had access to some form of ablution, 69% to flush toilets and 31 % to non-flush toilet.

4.3.7 Household electrical appliances

The availability of working household electrical appliances serves as an indicator of socioeconomic status of the households. The results obtained from the questionnaire are summarised in **Table 4.2**.

Table 4.2 Availability of electrical appliances for food storage, preparation and electronic media

Electrical appliance	Percentage
Refrigerator	23.6
Freezer	5.5
Both (Fridge & Freezer)	7.3
No fridge & Freezer	63.6
Stove	50.9
Microwave	0
Hotplate	10.9
Radio (only)	29.1
Television (only)	3.6
Both (Radio & Television)	41.8
No Radio and television	25.5

4.3.8 Employment status and household income

The rate of unemployment of the mothers was very high at 78.4%, only 0.07% of the mothers were housewives by choice. The mothers were regarded as unemployed if they did not have any source of income. Those that were regarded as employed (21.6%) were either wage earners or self employed. However, 71% of the fathers were employed while 29% unemployed. It was, however, not established if the fathers contributed financially to the upkeep of the home since most for the mothers were regarded as single. Eighty seven percent of the households had a combined income of below R1000 which was arbitrarily chosen as reasonable for subsistence. 72% of the households spent less than R200 of the total household income on food per month.

4.4 FACTORS INFLUENCING CHILDCARE

4.4.1 Nutritional knowledge

To determine the nutritional knowledge of mothers/caregivers, different questions were asked in a multiple-choice form. Interviewees were supposed to

Question 5

At what age should your baby be fed any of the following? (water, other milk products, soft porridge and others) (Greater than three months for all).

All but one of the mothers/caregivers said that water and milk products should be given to the child before three months. The one exception, said other milk products should be given after three months. The majority of mothers/caregivers said that soft foods (95,5% of mothers/caregivers) and other foods (85,6% of mothers/caregivers) should be given to the child before three months.

Question 6

When are you supposed to stop breastfeeding your child? (1 to 2 years or greater than two years).

There were two correct answers as shown above. Therefore, all the respondents who chose either of the two were regarded as knowing when to stop breastfeeding their children. More than 90% of the respondents knew when to stop breastfeeding their children.

Question 7

What should you use to give your child milk formula? (Cup).

Only 18.5% of the respondents knew that a cup should be used to give the child a milk formula.

Question 8

How many times per day should you give your child food? (On demand).

56% of the respondents indicated that the child should be fed on demand.

Question 9 & 10

Should you give in-between meals? (Yes).

More than 85% answered yes to the above question. A follow-up question on how many times they should give in-between meals was asked and 20.4% said that they should give in-between meals, three times a day.

Question 11 & 12

Should you add anything to your child's porridge to make it more nutritious? (Yes).

Of the entire respondents 98.2% said that they should add something to their child's porridge to make it more nutritious. A follow-up question of what should be added was asked. Answers included one or more of the following: sugar, oil/margarine, egg, milk, peanut butter, gravy, meat, fish or chicken with sugar. Oil/margarine were the most frequently reported.

On average the mean number of correct answers for all the questions was fair with a mean of 6.9 out of a possible 12. Out of a total of twelve questions, the lowest score was four and the highest score was nine. The maximum possible score was twelve. The results are shown in **Table 4.3**.

Table 4.3 *Summary of infant nutrition knowledge of mothers/caregivers*

Score*	
Mean	6,90
Standard deviation	1,08
Minimum	4
Maximum	9

*Score mean number of correct answers given during the interview
(Maximum score: 12 points)

4.4.2 Educational level

The educational levels of both the caregivers and the mothers were determined. There was no provision for “no education” (never attended school) and “do not know” in the case where the caregiver was interviewed and did not know the educational level of the mother. For educational level of the mother, one response was missing due to the above- mentioned reasons. All the mothers had received some form of formal education. The majority of mothers (32%) had grade 8 – 10 level and none of the mothers had post-matric education. The mothers were better educated when compared to the caregivers who had mostly a grade 1 – 4 qualification. Other data were missing (21) because there was no provision for “do not know” in the case where the caregiver was interviewed and was unable to answer the question.

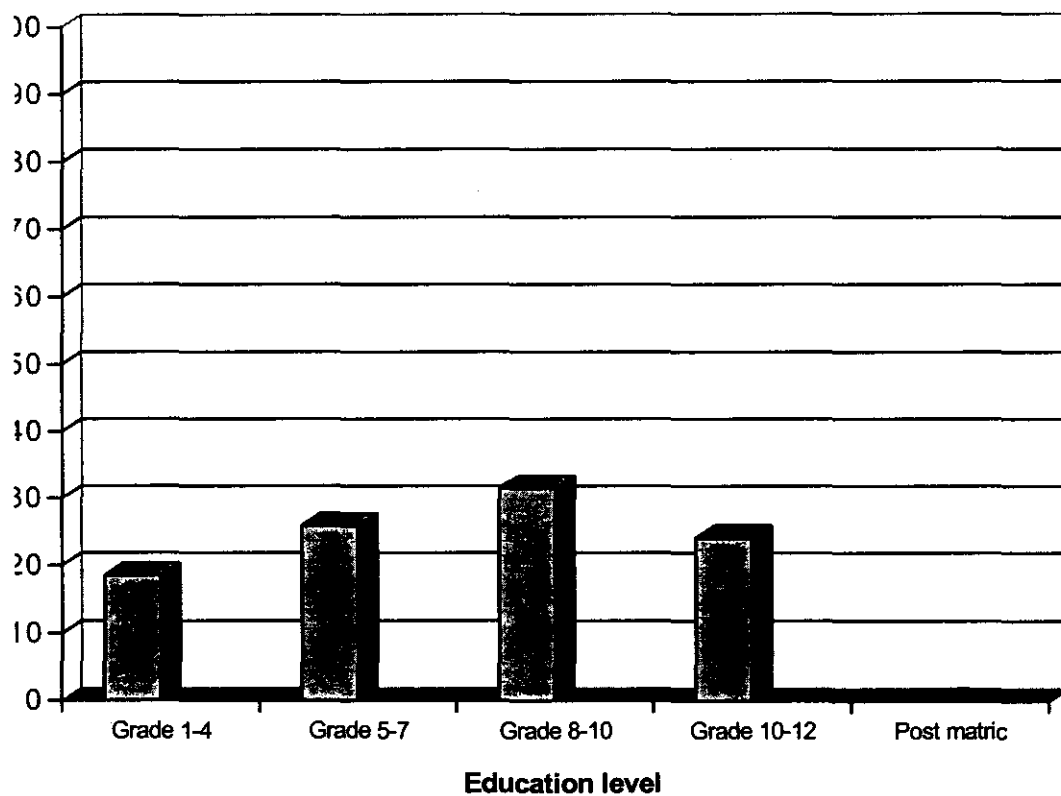


Figure 4.1 Educational level of the mother

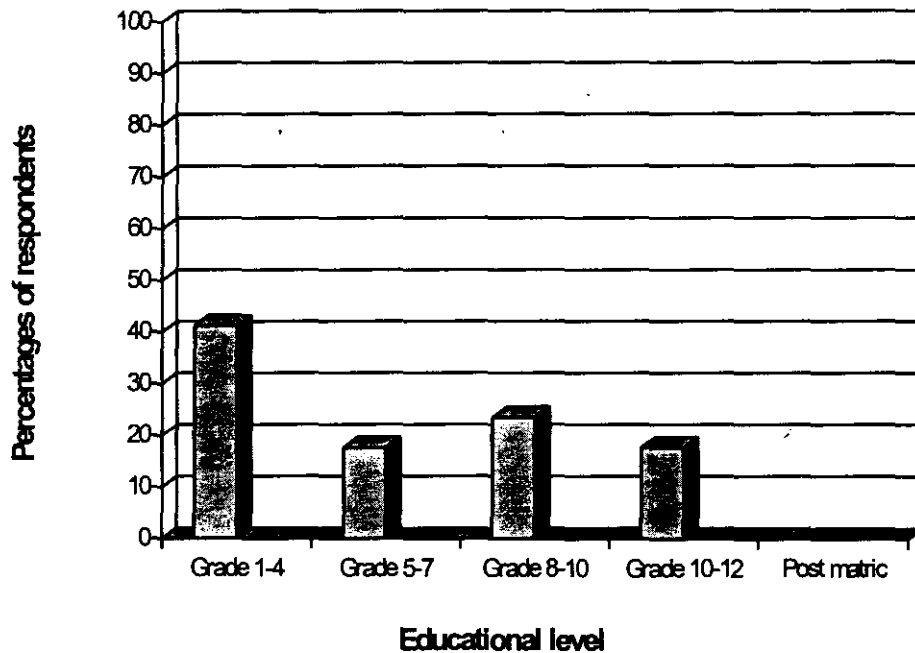


Figure 4.2 *Educational level of the caregiver*

4.4.3 *Family support*

To determine if the mother/caregiver received support from other family members, they were asked if they had an alternative caregiver. Using the available data, 61.8% of the respondents had alternative caregivers. Most caregivers were grandparents followed by aunts/uncles and the least being cousins and friends. Few fathers participated in childcare, with 11.8% of the fathers participating actively in child care (Figure 4.3).

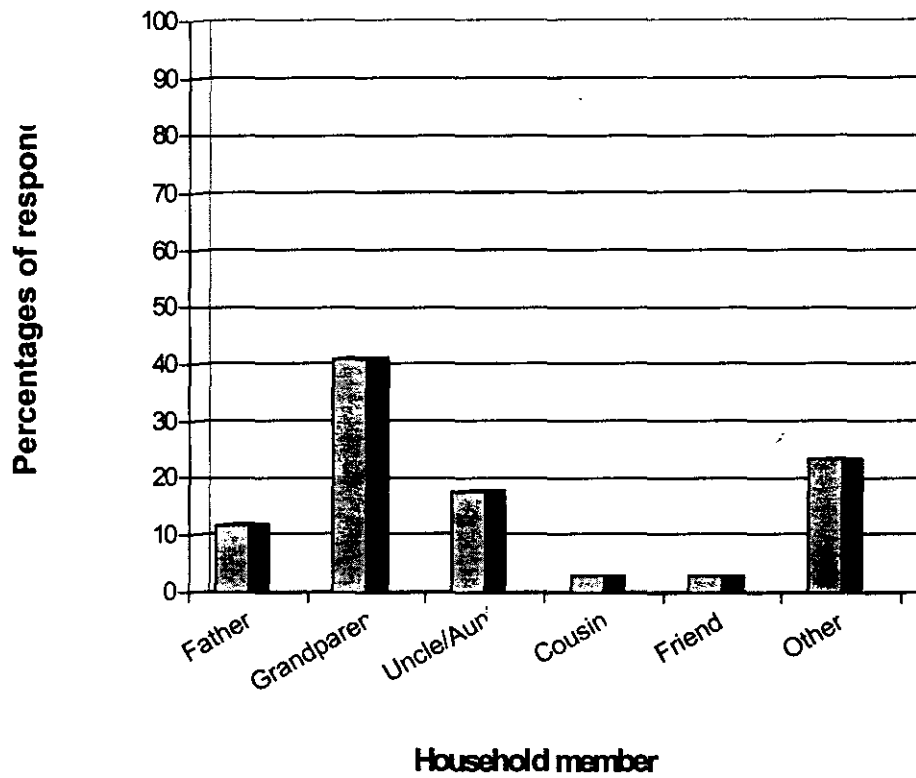


Figure 4.3 *Availability of alternative caregiver*

4.4.4 *Control of family resources*

It was important to find out who controls resources in the family, whether it is the mother or other family members. In 45% of households income was controlled by mothers (Figure 4.4).

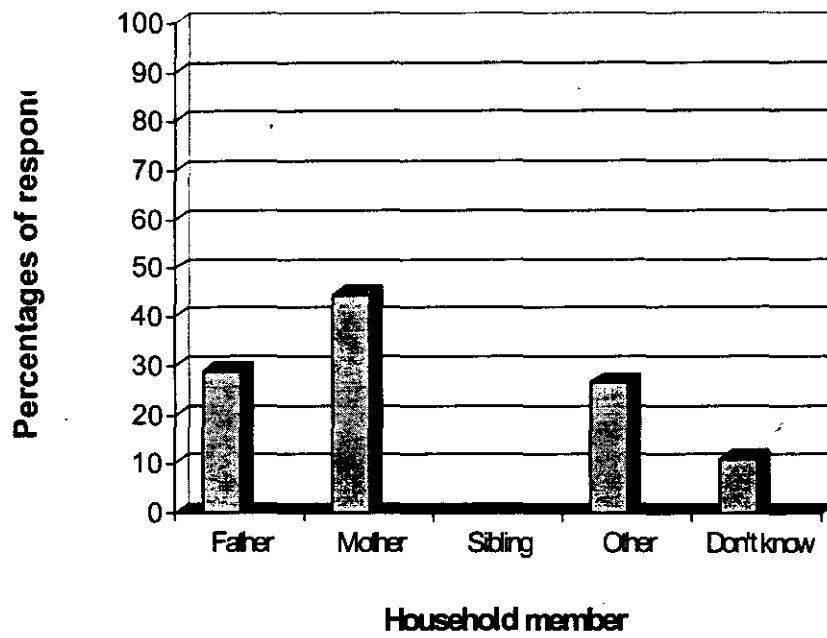


Figure 4.4 *Control of household income*

In 59% households the mothers were taking decisions on the amount of money to be spent on food. Nearly 11% of data was missing. This might be due to the fact that these households did not have income but depended on donations or gifts (*Figure 4.5*).

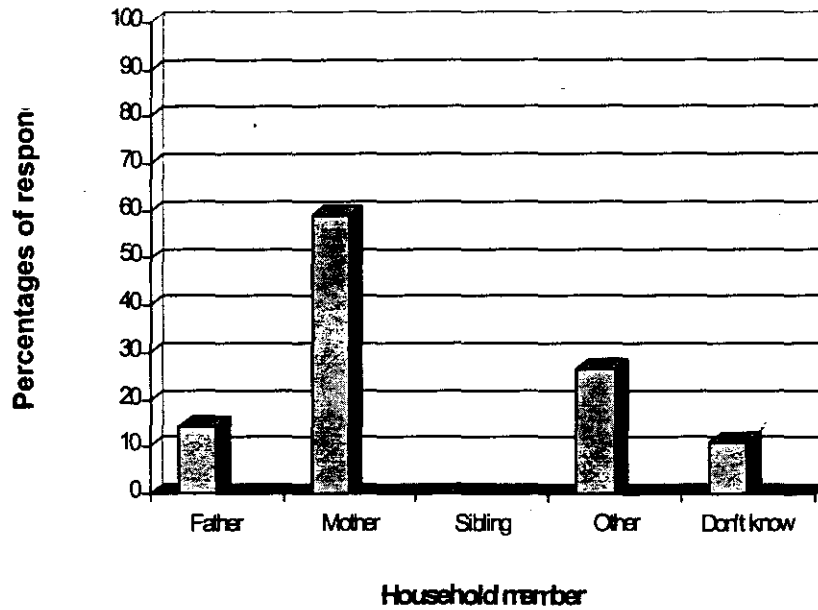


Figure 4.5 *Household members deciding on amount of money to be spent on food*

4.4.5 *Decision on type of food to be bought*

In 73.3% households, mothers took the decision on the type of food to be bought (68.6% and 77.8% experimental and control group respectively). Six responses were missing, five from the experimental group and one from the control group (*Figure 4.6*).

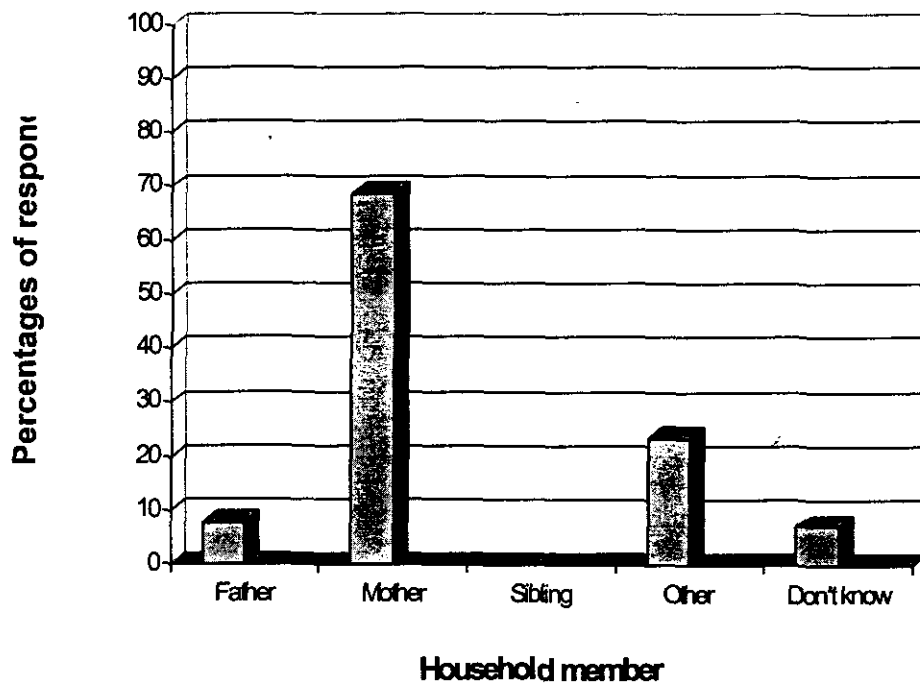


Figure 4.6 Household members deciding on type of food to be bought

4.4.6 Time availability and work load

To determine the workload, the number of hours spent on domestic and economic work was calculated. Total hours spent on fetching water, gathering wood, preparing food, doing the laundry, cleaning the house and other work were added together for domestic work. Economic work was calculated by adding the number of hours spent on agricultural labour, employment and any other activities for income. Data was obtained from only 15 respondents because some were not involved in economic work (Table 4.5). This indicates that few mothers/caregivers were involved in economic work.

Table 4.4 Summary of hours spent on domestic and economic work

Number of hours per day	Domestic work (n = 49)	Economic work (n = 15)
Mean	8,89	8,37
Std deviation	3,74	3,86
Minimum	4	1
Maximum	16	16

4.4.7 Hygiene practices

The field workers observed subjectively the environment in which the child lived and the cleanliness of both the child and the caregiver. On average the mean score for hygiene practices was 86.6; the maximum possible score was 105.

Table 4.5 Summary of hygiene practices

Score*	
Mean	86,6
Standard deviation	19,4
Minimum	21
Maximum	105

* Total number of clean variables (house, mother and child)

4.5 DIETARY INTAKE PATTERNS

As previously explained, the dietary pattern of the total group is reported here to give *inter alia* an indication why maize meal was chosen as a vehicle. Dietary intakes were obtained using 24 hour recalls that were conducted at baseline by interviewing caregivers. This assessment was not meant for comparison of the two groups, but to establish the pattern of intake by the children in the study group.

The most consumed food items were as follows in descending order of frequency reported:

- (i) Tea
- (ii) Sugar
- (iii) Maize meal (soft and stiff)
- (iv) Milk (fresh/powder)
- (v) Bread
- (vi) Pilchards

The meal pattern followed was that of three main meals per day with in-between snacks consumed by most children, especially those that had the day meals at the crèche. The main source of protein was milk either fresh or powder as well as pilchards. The most common vegetables consumed were potato, tomatoes and onions. All age groups ate maize meal porridge either soft or stiff as a staple. Bread was consumed mostly as a snack or with tea for breakfast.

Almost all the children drank tea with sugar as the first thing when they woke up. Soft porridge with sugar was the most commonly consumed breakfast for all in the age group 12 to 24 months. The older children (24 – 36) months ate bread with margarine and jam together with tea for breakfast. Soft porridge was consumed at mid-morning. Children who were over 1½ years were mostly attending crèche which is why they had soft porridge at ~10:00 and a more comprehensive lunch as compared to the children younger than 1½ years. This young age group normally had lunch comprising of stiff porridge with cooked packet soup (Royco/Maggie) or soft porridge with milk and sugar. The supper was mostly porridge either soft or stiff with milk. It must however, be highlighted that these children were also breastfed. The older children, as previously mentioned, ate their meals at the crèche and the lunch comprised of stiff porridge, pilchards mixed with potato and Soya mince and a tablespoon of butternut. They also had a luxury of eating a mid-afternoon snack of a slice of bread with jam and half an apple. The supper meal was similar to the other age group which was stiff porridge and milk. In general the consumption of

vegetables was poor and fruit was mostly consumed at the crèche. All the children in the study group consumed maize porridge as a staple and the consumption of bread in home meals was very low.

Table 4.6 shows that the 12 – 18 month old children usually consumed about 440g soft porridge per day. Soft porridge is prepared with cooking method 1 (section 3.8.2) in which a ratio of 3 parts water to 1 part maize meal is used. This means that children in this age group consumed an estimated average of about 150g maize meal per day, the amount chosen to fortify with 100% of the RDA of the respective vitamins. Similarly, the stiff porridge consumed by the older children is made with cooking method 2 (section 3.8.2) in which the water: meal ratio is about 2:1. Therefore, the 18 – 24 month old children were expected to consume at least 111g maize meal (125ml soft porridge plus 130g stiff porridge) per day and the older children 83g maize meal (165g stiff porridge).

4.6 ANTHROPOMETRIC DATA

4.6.1 *Height and weight*

Descriptive statistics describing anthropometric data for the study are presented in **Table 4.7 (a)**

The mean weight for the control group was slightly higher (10.5kg) as compared to that of the experimental group (9.9kg) at baseline. Both groups experienced an improvement in weight after the intervention period. The experimental group had a marked increase of 5.0kg (9.9 to 14.9kg: 5.0kg) compared to the control group's 3.3kg (10.5 to 13.8kg: 3.3kg). This difference was, however, not statistically significant when all children available at baseline and outcome were compared within groups.

The weights of the children in both groups were very close together as indicated by the low standard deviations for both groups, both at baseline and outcome.

Table 4.7(a) Descriptive statistics of anthropometric data of children aged 1 – 3 years residing in Oukasie, means (standard deviations) and 95% confidence intervals

Variable	Unit	Experimental Baseline (n = 21)	Experimental Outcome (n = 16)	Control Baseline (n = 23)	Control Outcome (n = 20)
Weight	Kg	9.9 (1.9)	14.9 (2.4)	10.5 (2.7)	13.8 (2.4)
95% Confidence interval		9.0 – 10.7	13.7 – 16.3	9.3 – 11.7	12.67 – 14.9
Height	Cm	76.2 (6.0)	87.9 (5.0)	76.1 (8.6)	90.0 (8.5)
95 Confidence interval	%	73.4 – 78.9	85.2 – 90.6	72.4 – 79.8	86.0 – 94.0

The height at baseline was very similar for both experimental and control groups (76.2 cm and 76.1 cm respectively). As with weight, both groups experienced an increase in height with the control group experiencing slightly higher gains (76.1 to 90 cm: 13.9cm) than the experimental group (76.2 to 87.9cm: 11.7cm). This difference, as in the case of the weight was not statistically significant.

When the children who had both baseline and outcome were compared, the experimental group exhibited a statistically significant ($p = 0.000$) increase in weight from a mean of 9.9kg at baseline to 14.5kg at outcome. This is a change of 4.6 compared to an even less gain in the control group of 2kg (11.9 to 13.9kg). The weight gain in the control group was also statistically significant ($p = 0.004$) but the p-value was much smaller in the experimental group. The change experienced by the control group is lower as compared to that when the whole group is assessed. This means that less children in the control group gained weight when only looking at those children that did not drop out. The mean weight gain for the control group was also below the expected weight gain of 2.4kg if no intervention was implemented. This is in contrast to the

experimental group which continued to exhibit marked weight gain, even in the smaller sample of children who did not drop out.

Table 4.7(b) Descriptive statistics of anthropometric data of children aged 1 – 3 years residing in Oukasié, comparing the same children. Means, (standard deviations) and 95% confidence intervals

Variable	Unit	Experimental Baseline (n = 16)	Experimental Outcome (n = 16)	Control Baseline (n = 16)	Control Outcome (n = 16)
Weight	Kg	9.9 (2.1)^	14.5 (2.5)^	11.9 (2.9)~	13.9 (2.6)~
95% Confidence interval		8.6 – 11.3	12.9 – 16.1	9.6 – 14.2	11.9 – 15.9
Height	cm	76.2 (7.2)^	87.1 (5.5)^	77.7 (7.5)^	88.5 (4.4)^
95% Confidence interval		71.5 – 80.7	83.6 – 90.6	72.0 – 83.5	85.2 – 91.9

^ Statistical significance (p = 0.000) (ANOVA)

~ Statistical significance (p = 0.004) (ANOVA)

Both groups experienced a statistically significant increase in height from baseline to outcome. The experimental group had an increase in height of 10.9cm (p = 0.000) and the control group had an increase of 10.8cm (p = 0.000). The trend was similar to when the whole group was assessed even though in the latter, no statistical significance was found.

4.7 BIOCHEMICAL DATA

4.7.1 Haemoglobin and haematocrit

The descriptive statistics of the haematological variables are depicted in **Table 4.8 (a)** below.

Table 4.8(a) *Descriptive statistics of haematological data of children aged 1 – 3 years residing in Oukasie, means (standard deviations) and 95% confidence intervals*

Variable	Unit	Experimental Baseline (n = 21)	Experimental Outcome (n = 16)	Control Baseline (n = 23)	Control Outcome (n = 20)	Normal values
Haemoglobin	g/dl	11.21 (1.49)#	11.43 (2.23)#	11.06 (1.37)	10.79 (2.37)	11.5
95% confidence interval		10.58 – 11.83	10.18 – 12.66	10.48 – 11.65	9.66 – 11.94	
Haematocrit	%	39.92 (5.78)	37.13 (2.60)	42.22 (5.15)	35.63 (4.02)	33–49
95% confidence interval		37.48 – 42.36	35.74 – 38.51	39.66 - 44.78	33.69 – 37.57	

Difference, statistically significant (ANOVA)

On average both groups had haemoglobin values below normal at baseline with the mean for the experimental group (11.21g/dl) slightly higher than that of the control group (11.06g/dl). The improvement of haemoglobin after the intervention was significant for the experimental group, whereas the control group experienced a reduction in the haemoglobin levels. On average, both groups had below normal values after intervention, though the experimental group was close to normal.

The mean haematocrit values of both groups were within normal ranges, both at baseline (39.9% and 42.2% for experimental and control group respectively) and outcome (37.1% and 35.6% for experimental and control group respectively). Both groups experienced a reduction in percentage haematocrit with the control

group experiencing a marked reduction (42.2% to 35.6%) as compared to the experimental group (39.9% to 37.1%). The differences experienced were not statistically significant.

Table 4.8(b) *Descriptive statistics of haematological data of children aged 1 – 3 years residing in Oukasi comparing the same children. Means, (standard deviations) and 95% confidence intervals*

Variable	Unit	Experimental Baseline (n = 16)	Experimental Outcome (n = 16)	Control Baseline (n = 16)	Control Outcome (n = 16)
Haemoglobin	g/dl	11.2 (1.20)	11.43 (2.23)	10.70 (1.70)	10.5 (2.40)
95% confidence interval		10.4 – 11.9	10.2 – 12.7	9.4 – 12.1	9.3 – 11.8
Haematocrit	%	40.08 (6.43)*	37.50 (2.75)*	43.55 (4.95)\$	34.67 (2.82)\$
95% confidence interval		35.99 – 44.17	35.75 – 39.25	39.74 - 47.36	32.49 – 36.84

* Statistical significance (p = 0.05)

\$ Statistical significance (p = 0.00)

The experimental group in this smaller group continued to show an improvement (11.2 – 11.43g/dl) in haemoglobin levels even though the difference is not statistically different. Interestingly the control group in this smaller sample experience a reduction in haemoglobin levels from 10.7g/dl at baseline to 10.5d/dl at end. This means that when comparing the same children in the control group from baseline to end the haemoglobin levels reduced by only 0.2g/dl. The trend with the haematological values was similar with that in the whole group whereby both groups experienced a reduction in the haematocrit levels. The control group however, experienced a greater and statistically significant (p = 0.00) reduction of 8.8% as compared to the experimental group (2.58%) (p = 0.05). The difference between the two groups is marked though it is not statistically significant. Even though the difference is

statistical significant in both groups, the statistical power is much greater for the control group. The results of the statistical test to assess the significant differences in changes of haemoglobin and haematocrit between the two groups are also shown in **Table 4.12**.

Table 4.8(c) Prevalence of anaemia from baseline to outcome for experimental and control group

Experimental		Control	
Baseline (n = 24)	Outcome (n = 15)	Baseline (n = 23)	Outcome (n = 19)
Anaemic	Anaemic	Anaemic	Anaemic
13 (54%)	6 (40%)	13 (57%)	13 (68%)

Anaemic Hb < 11.5g/dl

Non-anaemic Hb > 11.5g/dl

It is evident from the Table 4.8(c) that the experimental group enjoyed an improvement in their iron status as compared to the control group. It was further discovered that 77% of the children in the control group experienced a decline in haemoglobin level from baseline to outcome as compared to only 47 % in the experimental group.

4.7.2 Retinol and retinol binding protein

The descriptive statistics of retinol and retinol binding protein are indicated in **Table 4.9(a)** below.

The mean serum retinol values for both groups were above the normal range. This meant that on average both groups probably had adequate stores of vitamin A. The mean value for the control group at baseline (1.26µmol/l) was higher than the mean value for the experimental group (1.19µmol/l).

Both groups experienced a marked improvement in serum retinol values. The experimental group experienced a higher improvement (1.19 to 1.30µmol/l) when compared to the control group (1.26 to 1.35µmol/l) though the difference was not statistically significant.

Table 4.9(a) Descriptive statistics of retinol and retinol binding protein data of children aged 1 – 3 years residing in Oukasié, means (standard deviations) and 95% confidence intervals

Variable	Unit	Experimental Baseline (n = 21)	Experimental Outcome (n = 16)	Control Baseline (n = 23)	Control Outcome (n = 20)	Normal values
Retinol	µmol/l	1.19 (0.44)	1.30 (0.35)	1.26 (0.37)	1.35 (0.49)	>1.05
95% confidence interval		1.01 – 1.38	1.11 – 1.49	1.11 – 1.42	1.09 – 1.61	
RBP*	mg/dl	1.73 (0.57)	1.72 (0.56)	2.08 (0.94)	1.51 (0.41)	3.0 – 6.0
95% confidence interval		1.47 – 1.98	1.44 – 2.01	1.68 – 2.48	1.29 – 1.72	

* Retinol binding protein

However, in both groups the mean values of serum retinol remained above normal after the intervention period.

The mean retinol binding protein (RBP) values for both groups were far below the normal range (3.0 – 6.0 mg/dl). At baseline the control group had a higher mean RBP (2.08 mg/dl) as compared to the experimental group (1.73mg/dl).

However, after the intervention period, the control group experienced a marked decrease (0.57mg/gl) in RBP to 1.51mg/dl as compared to a decrease of just 0.01mg/dl experienced by the experimental group.

When these small samples of children who did not drop out, are compared from baseline to end, the situation with retinol exhibit the same trend as the in whole group. The control group, however, experienced markedly less improvement in retinol levels (0.03µmol/l) as compared to 0.11µmol/l experienced by the experimental group. Though the improvement is not statistically significant, it is marked when compared to the control group. This means that from the children

that did not drop out fewer children in the control group experienced an improvement in serum retinol levels.

Table 4.9(b) Descriptive statistics of retinol and retinol binding protein data of children aged 1 – 3 years residing in Oukasié comparing the same children. Means, (standard deviations) and 95% confidence interval

Variable	Unit	Experimental Baseline (n = 16)	Experimental Outcome (n = 16)	Control Baseline (n = 16)	Control Outcome (n = 16)
Retinol	µmol/l	1.19 (0.48)	1.30 (0.35)	1.28 (0.38)	1.31 (0.47)
95% confidence interval		0.85 – 1.36	1.02 – 1.51	1.09 – 1.45	1.03 – 1.84
RBP*	mg/dl	1.73 (0.57)	1.71 (0.67)	2.26 (1.13)@	1.47 (0.42)@
95% confidence interval		1.36 – 2.09	1.27 – 2.13	1.39 – 3.13	1.14 – 1.80

* Retinol binding protein

@ Statistical difference (p = 0.007) (ANOVA)

The levels of retinol binding protein of both groups decreased from baseline to end. However, the reduction in the control group was statistically significant (p = 0.007). The experimental group had an insignificant reduction of 0.02µmol/l as compared to the significant reduction on 0.79µmol/l experienced by the control group. The significant differences in changes of RBP between the two groups were confirmed with additional statistical calculations, shown in Table 4.13.

4.7.3 Classification of serum vitamin A levels for experimental and control groups

It is evident from Table 4.10 that all but one child had adequate to normal stores of retinol. The situation stayed the same at outcome, still with one child with marginal vitamin A deficiency. What is interesting was that it was not the same child who was deficient at baseline.

Table 4.10 The classification of serum retinol level of both experimental and control group at baseline and outcome (number of children and percentage per category)

EXPERIMENTAL						CONTROL					
Baseline			Outcome			Baseline			Outcome		
0.35-0.7*	0.7-1.05*	>1.05*	0.35-0.7*	0.7-1.05*	>1.05*	0.35-0.7*	0.7-1.05*	>1.05*	0.35-0.7*	0.7-1.05*	>1.05*
1	9	5	1	5	9	0	5	12	0	8	9
7%	60%	33%	7%	33%	60%	0%	29%	71%	0%	47%	53%

* $\mu\text{mol/l}$

Categories

0.35 – 0.7 $\mu\text{mol/l}$ = Marginal deficiency

0.7 – 1.05 $\mu\text{mol/l}$ = Adequate

>1.05 $\mu\text{mol/l}$ = Normal

In the experimental group, however, four subjects moved from adequate to normal whereas with the control group the same number of subjects moved from normal to adequate. This indicates deterioration in vitamin A status of the control group and the same degree of improvement within the experimental group.

4.7.4 Deterioration and improvement of serum retinol level for experimental and control group after intervention

Table 4.11 Percentage of individual children who showed an improvement as well as deterioration of vitamin A status after intervention

	Experimental	Control
Reduction in serum retinol	5 (40%)	10 (59%)
No improvement	0 (0%)	1 (6%)
Increase in serum retinol	10 (60%)	6 (35%)

Table 4.11 confirms the fact that the majority of children in the control group experienced deterioration in their vitamin A status as compared to the experimental group. In total, only 35% of the control group improved their vitamin A status compared to 60% of the experimental group.

Interestingly, in both groups a reduction in serum retinol levels was observed but the control group had a markedly higher reduction of 59% compared to 40% in the experimental group. Only one child in the control group had no improvement in the serum retinol levels.

4.7.5 Changes from baseline to outcome for haematological and biochemical data

In this section the results of a comparison of the changes in blood and serum variables are reported. Additional statistical tests were done to assess if these changes were significantly different between groups, and to confirm the findings as reported in **Tables 4.8 and 4.9.**

Table 4.12 *Change from baseline to outcome for hemoglobin and hematocrit*

	Hemoglobin Experimental	Hemoglobin Control	Levene's test	Hematocrit Experimental	Hematocrit Control	ANOVA Significance
Mean	4.93E-02	-0.61	0.82*	-3.06	-7.33	0.059**
Sd	1.81	2.29		5.66	6.42	
Lower Bound#	- 0.95	- 1.78		-6.08	-10.89	
Upper Bound#	1.05	0.56		-0.045	-3.78	

95% confidence interval

* No statistical significance

** Statistical significance

Though the change from baseline to outcome for haemoglobin in the experimental group was positive (4.93E-02) there was no statistical significance, even though the control group had a deterioration in mean value from baseline to outcome. However, it was evident that the experimental group experienced an improvement in haemoglobin values as compared to the control group.

The changes from baseline to outcome for haematocrit were negative for both groups but the reduction in the experimental group was significantly less than that experienced by the control group.

Table 4.13 *Change from baseline to outcome retinol and retinol binding protein*

	Retinol Experimental	Retinol Control	ANOVA Significance	RBP Experimental	RBP Control	ANOVA Significance
Mean	0.11	0.028	0.62*	-0.036	-0.73	0.032**
Sd	0.43	0.53		0.81	0.98	
Lower Bound #	-0.12	-0.25		-0.45	-1.25	
Upper Bound #	0.34	0.31		0.38	-0.21	

95% confidence interval

* No statistical significance

** Statistical significance

The ANOVA test results are depicted in **Table 4.13** above. The change from baseline to outcome for serum retinol was markedly higher for the experimental

group as compared to the control group. The difference was, however, not statistically significant with a P=0.62.

A different view, however, is evident with serum RBP where the change from baseline to outcome was statistically significant (P=0.032). The mean change for the experimental group was -0.036 compared to -0.73 for the control group. Though both groups experienced a reduction in mean RBP values the reduction for the control group was significantly greater (see Table 4.11).

4.7.6 *Relationship between observed changes*

In this section the results of a more in-depth statistical analysis of the data are reported. The objective was to assess the relationship between changes in the blood and serum variables and to assess if baseline variables influenced the change of the variables from baseline to end.

No significant effect between the baseline variables was found in the change of all the variables except for change in retinol. The test of between subject effect as well as the adjusted means for change in retinol is depicted in **Tables 4.14** and **4.15** below.

Table 4.14 *Test of between subjects effects*
Dependant variable: Change in serum retinol

Source	Type III Sum squares	Degree of freedom	Mean square	F	Significance (p-value)
Corrected model	2.963 ^a	6	0.494	4.881	0.004
Intercept	0.016	1	0.016	0.159	0.695
Weight	1.353	1	1.353	13.372	0.002
S. RBP baseline	0.924	1	0.924	9.129	0.007
S. Retinol baseline	1.924	1	1.347	13.312	0.002
Gender	0.075	1	0.075	0.745	0.399
Haematocrit	0.114	1	0.114	1.127	0.302
Group	0.357	1	0.357	<u>3.532</u>	<u>0.076</u>
Error	1.922	19	0.101		
Total	5.185	26			
Corrected total	4.886	25			

^a R squared = .607 (adjusted R squared = .482)

Compared with the level of significance for the unadjusted comparison between experimental and control groups, adjusting for weight, serum retinol at baseline and baseline serum retinol binding protein increased the between group F ratio and level of statistical significance. This suggests that the intervention in the experimental group had a greater effect on serum retinol levels among children who had lower baseline retinol and nutritional status. Table 4.16 (with unadjusted means in brackets) shows that adjusting for baseline retinol and weight, increases the apparent effect of the intervention. If it is assumed that the control group reflects what may normally happen over time, the expected decline in serum retinol was not seen in those children who received the fortified maize, although the effect was not statistically significant, mainly because of the small sample size and limited power.

Table 4.15 *Adjusted means, standard error and confidence interval for change in retinol*

Dependant variable: Change in serum retinol

Group	Mean	Std Error	95% confidence interval	
			Lower bound	Upper bound
Experimental (0.11)	0.250 ^a	0.098	0.044	0.455
Control (0.03)	-0.015 ^a	0.90	-0.203	0.174

^a Covariate appearing in the model are evaluated at the following values: weight= 10.6308, Serum RBP (baseline) = 1.9204, serum retinol (baseline) = 1.1696, Gender = 1.62, height = 77.5154

4.7.7 *Correlation between changes in serum retinol with haemoglobin*

Non-parametric correlations were done between the changes in serum retinol from baseline to end with the change of haemoglobin from baseline to end. The outcome is presented in **Table 4.16**.

Table 4.16 *Non-parametric correlation between changes in serum retinol and haemoglobin (spearman rank correlation)*

	Haemoglobin change	Retinol change
Haemoglobin change		
Correlation coefficient	1.00	+0.399
Sig. (2-tailed)	--	0.029*
N	30	30

* Correlation is significant at the 0.05 level (2-tailed)

Table 4.16 indicates that the change in serum retinol in both groups was significantly correlated to the change in haemoglobin. This is also a positive correlation, whereby the increase in retinol was directly related to the increase in haemoglobin. This occurred even in the absence of iron as a fortificant.

Table 4.17 *Non-parametric correlation between changes in serum retinol and serum retinol binding protein and other variables on adjusted means for the whole study population (spearman rank correlation)*

	Retinol baseline	Change height	Change weight
Serum retinol binding protein change			
Correlation coefficient	-0.441***	-0.452*	-0.171
Significance (2-tailed)	0.009	0.020	0.403
N	34	26	26
Serum retinol change			
Correlation coefficient	-0.430*	0.45	-0.420*
Sig. (2-tailed)	0.014	0.823	0.0290
N	3	27	27

*** correlation is significant at the 0.01 level (2-tailed)

* correlation is significant at the 0.05 level (2-tailed)

When the means were adjusted, there was a negative correlation observed between serum retinol at baseline, change in height as well as change in weight and the change in serum retinol binding protein. Other negative correlations

were observed between baseline serum retinol, and change in weight with change in serum retinol.

This meant that subjects with higher baseline retinol experienced a lower change in serum retinol from baseline to outcome. This applied to all the other variables as indicated in **Table 4.17**.

These negative correlations were also observed with the groups as follows; for the experimental group, the change in serum retinol was negatively correlated to baseline serum retinol ($r=-0.624$ & $P=0.010$) and for the control group, the change in serum retinol binding protein was negatively correlated to baseline serum retinol ($r=-0.146$ & $P=0.001$).

These observed changes during the intervention period, will be discussed in Chapter 5.

CHAPTER 5: DISCUSSION

5.1 INTRODUCTION

In this study, the effectiveness of fortifying a staple with multi-micronutrients was examined. The nutritional status of the children was measured through anthropometric variables, haematologic variables (haemoglobin & haematocrit) and serum retinol and retinol binding protein (RBP). A comparison was done of these variables from baseline to outcome within and between experimental and control groups. The significant differences in changes of these variables, as well as the relationships between changes were also assessed. The intervention period was ~ 1 year and the fortified maize meal provided ~935 – 1207IU additional vitamin A, folic acid, riboflavin and thiamine per child per day. Vitamin A status (serum retinol, RBP) was used as a marker for changes in biochemical nutritional status and haemoglobin and haematocrit were used as markers for haematological changes. Since insufficient blood samples were collected from the children, comprehensive serum vitamin analyses were not possible.

The salient observations in this study were that the experimental children gained a mean of 5.0kg in weight while the control group gained only 3.3kg; both groups showed statistically significant increases in height. The experimental group showed a statistically significant improvement in blood haemoglobin compared to a decline in the control group. Both groups experienced a decline in haematocrit but the change in the control group was significantly greater. Both groups experienced an increase in serum retinol and a decline in serum RBP. The decline of RBP was statistically significant greater in the control group. An analysis of the data further indicated that the fortified maize had greater effect in those children with lower baseline retinol and RBP levels. It was also observed that the changes in serum retinol were significantly related to changes in haemoglobin.

In this chapter the limitations of the study will be briefly discussed after which the meaning of the observed changes during the intervention period will be interpreted as well as the background of the environment in which these children live.

5.2 LIMITATIONS OF THE STUDY

5.2.1 *Additional vitamin A intakes by the experimental group*

As reported in Chapter 3, the fortified maize meal was tested for retention and it was found that the experimental group had ~935 – 1207IU available to them for very 150g dry maize meal. The amount, however, varied due to the cooking process. Cooking process 2 (see 3.8.2) which resulted in only 55% retention, is normally followed by young mothers who prepare food in a hurry and this method should therefore be discouraged. The test however, did not include losses incurred during storage when the porridge is consumed cold, the day after preparation, nor did it test whether there is a difference in retention if the maize meal is prepared as soft porridge versus stiff porridge. Because the exact intakes of fortified and unfortified maize by the children could not be assessed, the calculation of the exact intake of vitamin A per child was not possible.

5.2.2 *Calculation of sample size*

The mean differences in nutritional status variables observed between the two groups were often “substantial” but not always statistically significant. This was an indication that the sample sizes were too small as described below.

The effects of micronutrient supplementation on growth performance of stunted children have been studied in rural Ethiopia (Umeta, 2003), in Benin (Dossa, 2001) and in Indonesia (Dijkhuizen and Wieringa, 2001). In the Benin study, the effects of zinc supplementation on the growth of 200 breastfed infants were examined. Supplementation was sustained for six months at a daily dosage of 10mg elemental zinc. The changes in heights and weights of stunted and non-

stunted children who received zinc were compared to children who received a placebo. The stunted children who received zinc had a 6.3% greater increase in height and an 11.8% greater increase in weight than the stunted children who received a placebo. Compared to the above study, in this study, the control children also received the staple, maize. The only difference was that the maize received by the experimental children was fortified. It is, therefore, reasonable to assume that the smaller difference in growth and other variables could be expected between the experimental and control children in this study. However, the lack of significant differences may also be ascribed to the small samples sizes.

Using a method described by Snedecor and Cochran (1967) and expecting differences in changes of nutritional status variables between experimental and control children of 3 to 10%, one can calculate the required sample size to achieve significant differences at the 5% level of statistical significance, using the formula:

$$n = N/1 + N(L/ZpS)^2$$

Where: n = Sample size

N = Maximum "distance" that the sample mean will differ from the population mean with a 99%, 95% or 90% chance respectively.

S = Standard deviation

L can be calculated as $Cm/100$

Where: m = Sample mean

C = The expected change difference in %

Zp = Standard normal critical value for p% Confidence interval:

99% chance; Zp = 2.58

95% chance Zp = 1.96

90% chance Zp = 1.64

If n/N is small, the formula is:

$$N \cong (ZpS/L)^2$$

Therefore, using the mean weight (SD) variables of our experimental children at baseline, if a 10% difference in change is expected, the number of children

needed per group to show a significant difference would be calculated as follows;

$$n \geq \left[\frac{1.96 \times 2.1}{\frac{10 \times 9.9}{100}} \right]^2$$

$$n = 17$$

If a 5 % difference in change in weight is expected the sample size should have been:

$$n \geq \left[\frac{1.96 \times 2.1}{\frac{5 \times 9.9}{100}} \right]^2$$

$$n = 69$$

Using a 3% expected change in serum retinol, the sample size needed would be:

$$n \geq \left[\frac{1.96 \times 2.1}{\frac{3 \times 9.9}{100}} \right]^2$$

$$n = 192$$

However, when a 10% difference in change is expected in serum retinol, the number of children per group to show significant changes with a 95% confidence will be.

$$n \geq \left[\frac{1.96 \times 0.4}{\frac{10 \times 1.1}{100}} \right]^2$$

$$n = 50$$

Since retinol was the main marker for assessing effectiveness of the fortification, it therefore can be concluded that the sample size for both experimental and control should have been 50 for each group expecting a 10% difference in change between the two groups. Therefore, the sample size in this study was too small. The reasons for the small sample sizes were discussed in Chapter 4. In the following discussion of the results this should be understood and kept in mind.

5.2.3 *Measurements*

- *Serum samples*

During the first phase of the study, it was intended that blood collection would be drawn from the jugular vein by a registered medical doctor. The amount of blood drawn using this method was sufficient for all intended analyses but it was traumatic to the child as well as the mother/caregivers. It was then decided that blood would be drawn from the anterior cubital vein using the 23G-butterfly system. With the latter method, the amount of blood drawn was small though the method received favour from the mothers. These resulted in some selected children with no blood samples and were therefore excluded from the study. The majority of the collected blood samples were too little to do a complete vitamin analysis, and it was, therefore, decided to measure for serum retinol and RBP as markers of biomedical nutritional status.

- *Nutrient intakes*

Due to the small sample size individual dietary intakes were not analysed. The 24 hour recalls that were conducted at baseline were to determine the consumption of maize as a staple in the community as well as to determine the type of maize mostly consumed. This assessment was used to eventually determine the overall dietary patterns of the study population. However, it was not possible to compare the intakes between the two groups since the numbers within each group was less than 50, the number usually regarded as the minimum to obtain reliable nutrient intake analyses from the 24 hour recall method.

5.3 EFFECTIVENESS OF THE INTERVENTION

5.3.1 *Anthropometrical variables*

- *Weight and height*

In this study, both experimental and control group children experienced an improvement in weight after the intervention period as was expected. The experimental group's weight gain (5.0kg) was markedly higher than the weight gained by the control group (3.3kg). The mean difference of 2.3kg between the two groups was however, not statistically significant.

A similar trend was observed with height gains. Both groups showed marked improvement in linear growth. The control group gained more height (13.9cm) as compared to the experimental group (11.7cm). The mean difference of 2.2cm between the two groups was not statistically significant.

Children aged one year are expected to gain ~ 2.5kg over 1 year and those aged 2 years 2.2kg (NCHS,1977). This means that if no intervention was instituted and provided that all requirements (e.g. energy) for "normal growth" are met, the children should have gained on average 2.4kg. However, the experimental group gained 5.0kg as compared to the 3.3 kg gained by the control group. It can, therefore, be assumed that the intervention contributed an additional 2.6kg in weight gain in the experimental group as compared to only 0.9kg of the control group. It can be presumed that the intake of maize by both groups increased their overall energy intake; it can also be presumed that the fortification of the maize with the other B vitamins could have improved the metabolism of energy in the experimental group. This demonstrates that dietary conditions for normal growth were probably not met in these children, but provision of free maize and the fortification of their staple food possibly improved these conditions.

With a larger sample size a difference in weight of 2.3kg could have been significant. The majority of the children in the study population were still

breastfed; this might have influenced the intake of the maize meal as the child had the option of breast milk or even bottled milk.

When the children who had both baseline and outcome measurements were compared, the experimental group exhibited a statistically significant ($p = 0.000$) increase in weight gain from a mean of 9.9kg at baseline to 14.5kg at outcome. This is a change of 4.6kg compared to an even less weight gain in the control group of 2kg (11.9 to 13.9kg). The weight gain in the control group was also statistically significant ($p = 0.004$) but the p-value was much smaller in the experimental group and therefore highly significant. The change experienced by the control group is lower as compared to that when the whole group is assessed. This means that less children in the control group gained weight when only looking at those children that did not drop out. This is in contrast to the experimental group which continued to exhibit marked weight gain even in the smaller sample of children who did not drop out.

Both groups experienced a statistically significant increase in height from baseline to outcome. The experimental group had an increase in height of 10.9cm ($p = 0.000$) and the control group had an increase of 10.8cm ($p = 0.000$). The trend was similar to when the whole group was assessed even though in the latter, no statistical significance was found. These results indicate that fortification of the staple food did not influence linear growth of the children who participated in this study.

The outcomes of this study are similar to those reported by Oelofse (2001) who found no significant difference in anthropometric parameters in infants who received fortified cereal for 6 months. In other studies where supplementation was used, conflicting results were found in terms of effect on growth. The majority of the studies found no significant difference in growth (Fawzi *et al.*, 1997 and West *et al.*, 1997). It seems that significant difference in growth is only attained by children who are severely vitamin A deficient as was found by West *et al.* (1997). The author showed a significant difference in children that had xerophthalmia at baseline. Other studies that yielded significant differences were those that concentrated only on stunted children. Thu *et al.* (1999) and

Umeta (2003) found that if they isolate children that are stunted from a bigger study group, a significant difference in growth was observed. Villamor *et al.* (2002) also found a significant difference in growth after supplementing HIV positive children with vitamin A. HIV positive children are likely to be severely undernourished and micronutrient deficient. Although the children in this study were not tested for HIV infection, none showed the obvious signs of accompanying opportunistic infections and it was assumed that they were HIV negative.

From the literature it can be concluded, therefore, that vitamin A fortifications and supplementation yields significant improvement in growth if severely malnourished and vitamin A deficient children are studied. In this study the majority of the children were underweight (mild to moderate under-nutrition) and none of the children were found to be severely vitamin A deficient; only one child was marginally vitamin A deficient. Nevertheless, the fortified maize significantly improved weight gain despite having no effect on height.

5.3.2 *Haematological variables*

- *Haemoglobin*

The experimental group exhibited an improvement in haemoglobin (11.21 to 11.43 g/dl) as compared to the control group who experienced a decline in haemoglobin in the intervention period. This indicates that the vitamin A fortification probably had a positive effect on iron status in this study. Of all the vitamins that could have influenced haemoglobin, vitamin A is probably the best candidate, since there is considerable evidence of the synergistic interaction between vitamin A and iron metabolism. Vitamin A is known to play an important role in haematopoiesis (Semba *et al.*, 1992). Vitamin A is necessary for blood regeneration since no regeneration can take place without vitamin A. It was also found that the quantity of vitamin A consumed have an effect on the rate and intensity of blood regeneration (Bloem, 1995 citing Koesler *et al.*, 1926). Both iron and vitamin A are transported by the acute phase proteins; transferrin and retinol binding protein, respectively. Iron is usually trapped in the liver and spleen and retinol binding protein is depressed in times of

infection. The administration of vitamin A seems to aid in the stimulation of retinol binding protein and transferrin, thereby releasing the trapped iron (Thurnham, 1993). Other studies that yielded positive results on haemoglobin after increased intake of vitamin A include studies by Bloem *et al.* (1989) and Van Stuivenberg *et al.* (1997). The significant positive correlation found in this studies between changes in haemoglobin and serum retinol (Spearman's rho: $r = +0.399$; $p = 0.029$) supports the observation that improvement in serum retinol, also improve iron status.

A child is classified to be anaemic if the haemoglobin level is below 11.5g/dl. In this study the mean values of both groups were anaemic at baseline as well as end. The experimental group, however, experienced a decline in the number of children who were anaemic from 54% to 40 % compared to an increase in incidence (57% to 64%) experienced by the control group [Table 4.8(c)].

The benefits of the improved iron status in the experimental group are immense when considering the cost of iron deficiency. These benefits include (USAID, 1995):

- Improvement in productivity later in life;
- Improvement in aptitudes, capacity to focus attention and school attendance;
- Reduction in health care costs due to fewer health complications and
- Reduction in risk of maternal mortality.

This study supports other observations that iron deficiency anaemia is the most prevalent nutritional deficiency in the developing world (Latham, 1990). There is also an indication that iron should have been added to the fortification regime in this study. This was not done because during the time of the study there was still debate on the efficacy of fortifying maize with iron. There were fears that unacceptable organoleptic changes were going to occur. The high prevalence of iron overload in the African population was also a deterrent. It is, however, now recommended that iron fortification of maize should be done.

- *Haematocrit*

Haematocrit reflects the contribution of blood cells to the total volume of blood (Meyer *et al.*, 1988). The haematocrit of healthy adults varies from 42 – 52% for men and 37 – 47% for women. It is usually high in new born children and in people living at high altitudes (Meyer *et al.*, 1988). It increases with increased red cell production and decreases with large decreases in circulating red cells. Low values of haematocrit indicate anaemia. The mean levels of children in this study varied from 35.6% to 42.2%.

Both groups experienced a decline in haematocrit level from baseline to end. The control group, however, experienced a greater decline in haematocrit level (6.6%) compared to the experimental group (2.8%). The greater decline in the control group resulted in that the mean change in haematocrit concentration of the experimental group ($-3.06\% \pm 5.66$) was significantly higher ($p=0.05$) when compared to the control group (-7.33 ± 6.42). Vitamin fortification seems to have arrested the decline in haematocrit concentration experienced by the experimental group. This is also an indication of the positive interaction between vitamin A and iron that was described above. All the studies reviewed did not assess haematocrit values as an indicator of iron metabolism. All of them only assessed haemoglobin.

It can, therefore, be concluded that the fortification of maize with vitamin A had a positive effect on the iron status of the children in the experimental group. However, it is still recommended that iron is added to the staple food of the affected population, because of the poor iron status observed and the failure of the vitamin fortified maize to correct iron status fully.

5.3.3 *Biochemical variables*

- *Retinol*

Both the experimental and control group experienced an increase in mean serum retinol levels (1.19 to 1.30 μ mol/l and 1.26 to 1.35 μ mol/l respectively). The experimental group experienced a greater increase (0.11 μ mol/l) as compared to the control group (0.09 μ mol/l). This difference was, however, not statistically significant. However, the results indicate that vitamin A fortification managed to improve the serum retinol level to a higher level in the experimental group and in those children who had the lower serum retinol levels at baseline. The insignificance of the change could be attributed to the small sample size, also caused by the insufficient collection of blood samples. The effect of baseline variables is significant but the sample is too small to indicate a significant effect of the intervention. In the study by Oelofse (2001) both experimental and control groups experienced a decline in serum retinol after the intervention period. Lartey *et al.* (1999) also found results similar to those of Oelofse (2001). Their control group had a decline in serum retinol levels and the experimental group a slight increase in serum retinol levels. The explanation of the decline experienced in these two studies could be the age of the study population. Both study populations were 6 months old at baseline which is the age when the infants are often introduced to solids and weaned from the breast. The vitamin A content of breast milk is inadequate to meet the needs at this stage (UNICEF, 1998). Therefore, the weaning practice of the mother could also play a role in vitamin A status.

Further investigations were done in this study. The individual serum retinol values were classified according to the WHO classification (Table 4.9). There were no children that could be classified as suffering from vitamin A deficiency. Only one child in the experimental group was marginally deficient. However, when looking at the movement of children through the different categories, the results showed that the children in the experimental group who were classified as “normal” increased by 27% during the intervention period as children from the adequate category experienced an improvement in vitamin A status. The

opposite occurred with the control group whereby the percentage of “normal” children declined by 18% from 71% to 53%.

This means that vitamin A fortification was able to improve the vitamin A status of individual children from adequate to normal. This was confirmed by the results illustrated in Table 4.10. From the table it is evident that 60% compared to 35% (experimental and control respectively) of individual children experienced an improvement in serum retinol levels. A higher percentage of the individual children in the control group (59%) experienced a decline in serum retinol level as compared to the experimental group (40%). This is indicative of the fact that vitamin A fortification was able to arrest the most common occurrence of declining serum retinol level in 60% of the individual cases in the experimental group, whereas almost the same percentage experienced a decline in the control group.

In conclusion, the fortification of maize with vitamin A seems to have had a positive influence on vitamin A status of the experimental group when serum retinol values are used to depict vitamin A status. This is known to have a positive impact on morbidity (Fawzi *et al.*, 1997) as well as the efficacy of immunisation (Bhaskaram & Rao, 1997). It can also be assumed that if the children were severely or marginally vitamin A deficient the effect of the fortification would have been greater.

- *Retinol binding protein (RBP)*

The RBP for both groups was far below the normal at baseline. Both the experimental and control groups experienced a decline in RBP with the control group experiencing a marked decline. The mean decline from baseline to outcome of the control group ($-0.73\text{mg/dl} \pm 0.98$) was significantly greater ($p=0.03$) than the decline in the experimental group ($-0.04\text{mg/dl} \pm 0.81$). The increased intake of vitamin A in the experimental group during the intervention period may have contributed in arresting a similar decline to that noted in the control group. As discussed earlier, the presence of infection can cause a depression in RBP and only the activation by vitamin A administration will

cause the release of RBP (Thurnham, 1993). This is a confirmation of the above results in that, vitamin A fortification in this study resulted in a positive association with vitamin A status of the children in the experimental group. It can also be deduced from the below normal RBP values at baseline and outcome, that the children could have been suffering from underlying infections. The fact that the experimental group experienced a much lower decline could be indicative to the anti-infection properties of vitamin A (Thurnham, 1993). This can also explain the insignificant improvement in serum retinol levels experienced by both groups. This deduction is in line with the findings on the socio-demographic questionnaire of the households. These children lived in an area which scored poorly in the sanitation score as compared to households that had well nourished children.

The performance of RBP was compared with serum retinol as indicators to classify children with vitamin deficiency. The correlation between the parameters was very good ($r=0.94$). Although RBP is affected by vitamin A deficiency, serum retinol is also influenced by protein status. RBP is a valid, quick and cheaper surrogate for serum retinol for assessing vitamin A status (IVACG, 2001).

It can be concluded, therefore, that vitamin A fortification had a positive association with vitamin A status as shown by the serum retinol levels. Vitamin A seems also to have aided in reducing the negative effect of sub-clinical infections. However, the prevalence of infections in the community has not been measured and should be looked at. It could be the poor socio-economic status of the children that might have played a role. In general terms it could be advised that mothers should be educated to be able to detect if a child is feverish and also to send the children for medical intervention much sooner.

The serious consequences associated with nutritional deficiencies that are rife in developing countries urged political and health leaders to set goals that include the virtual elimination of vitamin A by 2010 and iodine deficiency by 2005 as well as the reduction of iron deficiency anaemia (UNICEF, 1990). The South African government set itself a goal of reducing the infant and under-five

mortality rate by one third to 50 and 70 per 1000 live births between 1995 and 2000 (Steyn, 2000). By 1999 this goal was achieved with the infant and under-5 mortality rate of 47 and 66 per 1000 live births (SA Health Review, 1999). This is a great step forward but the goals for the reduction of malnutrition remain unachieved. Deficiencies of vitamin A, iodine and iron intakes are still very common in the disadvantaged communities of South Africa (Labadarios *et al.*, 2000).

5.4 ENVIRONMENTAL PROFILE OF PARTICIPATING CHILDREN

5.4.1 Introduction

As mentioned in Chapter 1, the South African Government's intended micronutrient fortification of maize meal and bread flour, motivated this study in which the effectiveness of vitamin fortification of maize meal to address under-nutrition was assessed. The consequences of micronutrient deficiencies include linear growth retardation, impaired psychomotor development, increased morbidity and reduced appetite (Oelofse, 2001). The UNICEF's conceptual framework of the aetiology of malnutrition is depicted below (Figure 5.1). This framework classifies the different determinants of malnutrition. The framework will now be used to contextualise the discussion of those variables measured in this study, which could have influenced the observed results.

The highlighted areas in Figure 5.1 indicate the determinants that were assessed in this study. The results from the questionnaires were not meant for comparison of the two groups but to provide a profile of the environment from which the children are coming from.

5.4.2 Socio-demographic information

Several variables were assessed in order to determine the social profile and environment from which the study population was recruited. It was encouraging to observe that most of the respondents (87%) were mothers; this meant that the

information collected through the questionnaires can probably be regarded as reliable. This was better than what was found in the National Food Consumption Survey where only 63% of the respondents were mothers. The lower percentage for the survey could have been due to the fact that all interviews were conducted during the day when most of the mothers might be at work. In this study the fieldworkers were from the study area and, therefore, could visit the mothers after hours.

The majority of the mothers (78%) were also responsible for food preparation and feeding the child. This is regarded as a good practice, since care by anyone but the mother or competent adult in the first years of life is associated with higher infant mortality (Engle, 1992, and Engle *et al.*, 1996). The percentage of mothers who were responsible for food preparation and child feeding was also higher than that found in the NFCS (63%). In the national survey, grandmothers tended to play a much bigger role than in this study. However, there is commonality when it came to the involvement of fathers in food preparation and child feeding. Only 2 % in the NFCS and none of the fathers in this study helped in food preparation and child feeding. The difference between the two studies could be the higher percentage of married mothers in the NFCS as compared to this study. This aspect will be discussed later in this chapter. The fact that fathers do not participate in food preparation is probably a cultural one whereby fathers or men feel that food preparation and child care are duties of the mother or any other female in the household (normally the grandmother or an older sister). Similar results were also found with the THUSA study: only one child out of 145 was cared for by the father (Lemke, 2001). One third of the THUSA children were care for by mainly the grandmother and others such as sister or mother-in-law (Lemke, 2001). In this study only 19% of the children were cared for by the grandmother and 3.8% by an older sister.

A mother was regarded as single if she was unmarried, widowed or living without a partner. According to this definition, 63% of the mothers were regarded as single. This compared well with the findings of the NFCS, were 67% of the mothers from the North West Province were single. The NFCS, however, found that nationally 50% of the mothers could be regarded as single.

From the THUSA study, 50% of the households were female headed as compared to 12.7% which were male headed and 37.3% which were jointly headed (Lemke, 2001).

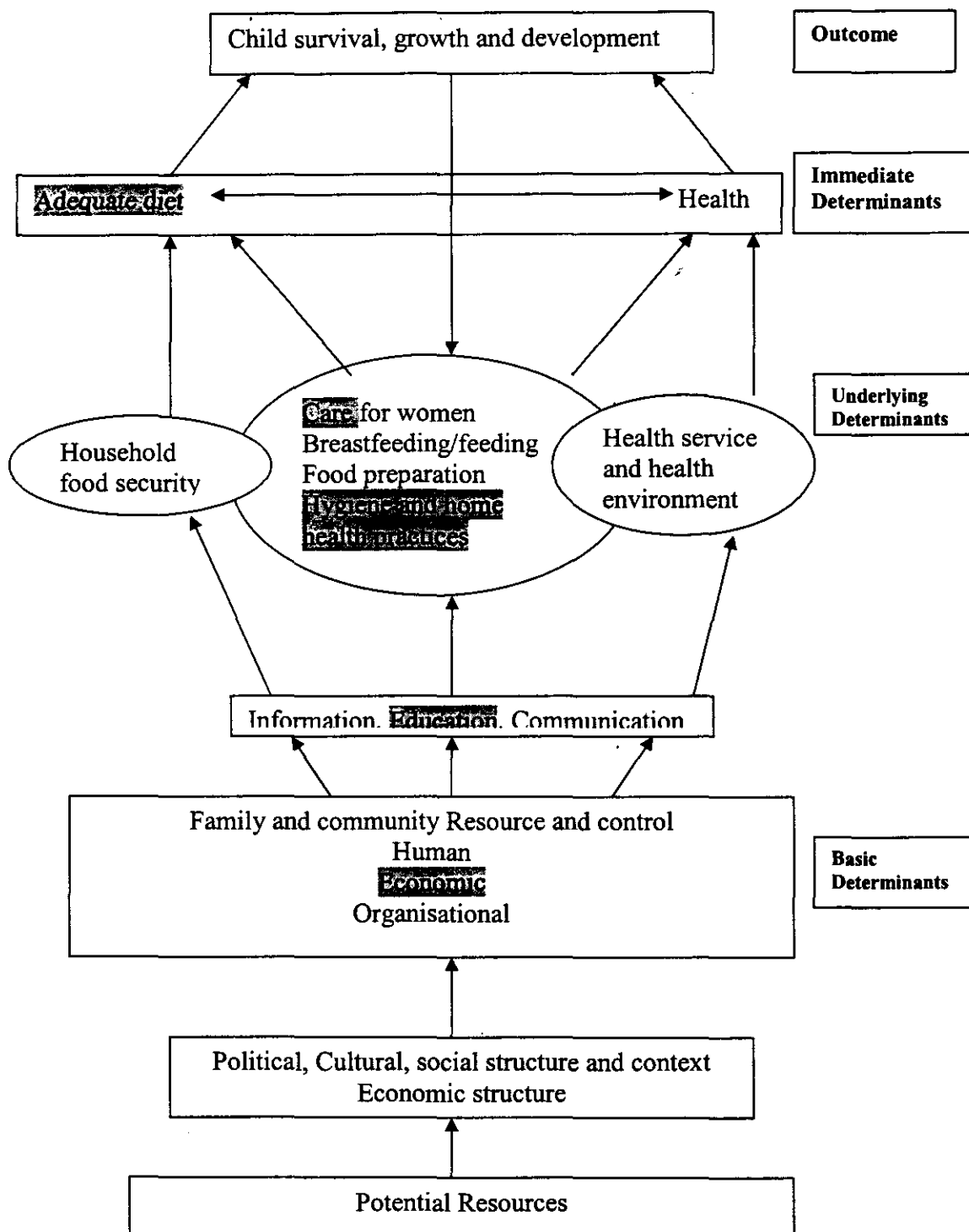


Fig 5.1 Conceptual framework of the determinants of child survival (Adapted from UNICEF, 1990)

Krige and Senekal (1977) cited by Steyn *et al.*, (1998), reported that children of unmarried mothers were more likely to be undernourished as compared to those of married mothers. Contradictory findings were reported by Wandel (1995) who found that children from female headed households had better nutritional status compared to those from male headed households. The contradiction here could be caused by the fact that in South Africa, the extent of dependency on fathers by mothers especially, in rural areas, is very high since many women were not involved (at least in 1977) in income generating activities. This left them fully dependant on the father who often was a migrant labourer in the cities, leaving the mother as a *de facto* female head of the household (Lemke, 2001). In Tanzania where Wandel (1995) conducted his study, women are fully responsible for crop and livestock production and they are therefore not fully reliant on the child's father for the provision of sufficient food and nutrition to the child (UNICEF, 2000).

In South Africa the practice of migrant labour is forced by increasing poverty and unemployment in rural areas resulting in the majority of families staying apart. This has a negative impact on the food security in the households (Lemke, 2001) and on the nutritional status of the children. This on its own will influence the dietary intake aspect of the UNICEF conceptual framework resulting eventually into malnutrition. The programmes as described in Chapter 2 that were implemented in Tanzania and Thailand may be advisable as they lift the position of the women in the community to be responsible for food production and, therefore, reduce their dependency on the migrant worker father or husband. Even though adjustments are made to households to cope with the disintegration of households through sibling households and kin headed households (mostly pensioned grandparents), there is no guarantee on the outcome of such adjustments. In the THUSA study 24% of the households depended on the pension income of the granny. This type of adjustment was found to be unsuccessful since the grandparents are usually abused by the older children for their pension money. At the end the young children and the grandparents are left at a nutritional disadvantage (Lemke, 2001).

The majority (78%) of households in the study population resided in homes built of mud, tin or wood. These houses were regarded as informal. Paraffin was the most commonly used fuel for cooking followed by wood/coal and then electricity. The type of dwelling, income and availability of working electrical appliances can be regarded as a good indicator of the economic status of the household. In contrast with 33% in the NFCS, the majority (78%) of the households lived in informal housing settings. This, however, should be seen in the light that Oukasie was chosen for its seemingly low socioeconomic status and therefore most of the households in this study were poor.

In terms of the type of fuel used for food preparation, paraffin (65%) was the most used as compared to electricity (45%) in the NFCS. The food consumption survey had paraffin as the second most used fuel in 30% of the households. If one looks at the North West Province the outcomes of this study is similar to the NFCS since paraffin was the most commonly used source of fuel with 47% for paraffin and 34% for electricity. This has a negative bearing on the hygienic preparation of food. Since it takes long to boil water on a primus stove, most of the elements in baby food preparation requiring the boiling of water will not be fulfilled, leaving the child at risk of developing gastrointestinal infections. The consequences of such infections on the nutritional status are well known.

The other indicator of economic status was the availability of electrical appliances in the household. The majority of the homes did not have a fridge (76.4%) or a freezer (94.5%). The implication for this is that these households are unable to purchase items like meats, dairy and fruits and vegetables in bulk to be stored. This is an added disadvantage since they are unable to take advantage of cheaper prices when buying in bulk. It also means that the sanitary storage of food is not possible, which will augment the problem highlighted when discussing the source of fuel used for food preparations. Insufficient cooking and reheating of food and storage of food at the incorrect temperatures that promote growth of pathogens are the main two practices that increase the risk of food contamination (Engle *et al.*, 1997).

The problem of sanitation is also highlighted by the fact that almost a third of the households did not make use of flush toilets. This is a high percentage, especially when one considers the negative hygiene implications of a non-ventilated pit toilet.

Unemployment is very high in South Africa and it continues to rise. This fact was confirmed in this study whereby 78.4% of the mothers were unemployed. Similarly, the NFCS found that 62% of mothers were unemployed. These statistics are serious considering the fact that most of these mothers were not married or staying with the fathers of the children. Therefore, even though 71% of the fathers were employed, their financial contribution to the family is questionable when one considers the discussion earlier in this chapter.

- **Economic**

In the sub-study by Tladinyane (2003) it was concluded that these children were of a low economic level as compared to households that had well nourished children. In her conclusion she found that the economic status was a major contributor to nutritional status in children residing in Oukasië. The difference in economic status of the households in this study as compared to households with well nourished children was statistically significant. This was found investigating variables such as income, employment status, electrical appliances, as well as type of dwelling. The study also found that there was a significant difference in the availability of flush toilets between the households in this study and those with well nourished children. The availability of flush toilet could also be seen as an indicator of economic status or poor municipal services.

As discussed above, and shown in Figure 5.1, economic aspects are regarded as basic determinants of the nutritional well being of the child. In this study households with undernourished children were financially disadvantaged; therefore, there will be insufficient money to provide for food, proper health service and also to ensure a healthy and hygienic environment in the home (Tladinyane, 2003). This means that these children are likely to have poor

access to adequate food due to poverty. The households are likely to be food insecure resulting in an inadequate diet. The outcome, therefore, will be an undernourished child. The households with well nourished children from the study area had a significantly better economic status, and it can thus explain the better nutritional outcome (Tladinyane, 2003)

- **Care**

This aspect was thoroughly investigated by Tladinyane (2003) and several aspects that are known to influence care were assessed. This included: nutritional knowledge, hygiene practices, educational level of the mother and caregiver as well as the time available for the mother to care for the child.

The mean score of the mothers/caregivers on the nutritional knowledge questionnaire was 6.9 out of a possible 12. In this regard, the nutritional knowledge of the mother was barely above 50% with an average score of 58% (6.9 out of a total of 12). This is by all means not ideal and it could be a strong factor in determining the capacity of the mother to offer proper care to the child. Even though the nutritional knowledge of the mothers with well nourished children was not significantly higher than the study group, there is a distinct need for nutritional education in the community. The knowledge of the mothers on breastfeeding was acceptable. Though the breastfeeding practice was not assessed there is also a need of lactation knowledge input in the community, especially when considering the poor economic state of the households with undernourished children.

The workload and time available for child care is usually limited if there is no support for the mother in caring for the child (Labadarios *et al.*, 2000). In this case the workload and time availability was similar for mothers of undernourished and well nourished children (Tladinyane, 2003). In another study by Begin *et al.* (1999), caregiver workload was not found to be a predictor of child nutritional status even when other factors were controlled. However, it should be borne in mind that self reported workload is not reliable, only direct

observation by the researcher is accurate in assessing this aspect (Engle and Lhotska, 1999).

The hygiene practices of the households were subjectively reported by the fieldworkers. From their impressions a significantly higher percentage of households of undernourished children obtained low scores for household and personal hygiene as compared to households of well nourished children. This is a common finding as the same results were found by the following researchers (Johnston *et al.*, 1980; Gopaldas *et al.*, 1988, Gobotswang, 1998 and Abate *et al.*, 2001).

This means, therefore, that children in the study group were exposed to another element contributing to malnutrition that exposes them to gastrointestinal infections since they were not kept clean, the house, their mothers, the playing area and the cooking utensils were not clean and most importantly the water used for drinking was not covered. This could be due to the lack of knowledge on the importance of hygiene or the poor socio-economic state of the household. The poor socio-economic status will contribute to the lack of sanitation facilities and the availability of clean running water in the yard as many of the study population collected water from communal taps.

The educational level of a mother improves the capacity of the mother to care for her child (Ruel *et al.*, 1999). In this study, the educational level of mothers and caregivers of undernourished children was lower than that of well nourished children although this was not statistically significant. A high level of education is associated with lower prevalence of stunting, underweight and wasting (Engle *et al.*, 1996). The other disadvantage of poor education is the reduction of employment opportunities which was found to also be the case in the study group. The low education and employment could have contributed to the poor socio-economic state of the study group.

5.4.3 *Dietary patterns*

The results in this study indicated that tea, sugar and maize meal were the top three foods which were frequently consumed by the children in the study population. Maize meal was confirmed as the most consumed staple in the study population. Maize meal was consumed mostly in two forms *viz.* stiff porridge consumed mostly by the older children for lunch and supper and soft porridge consumed by most children for breakfast and for lunch and supper by the younger children.

The children in the study population consumed three meals a day which is common for the North-West province. Franz (1971) described the diet of the Tswana's of the North West Province as traditional and comprising of sorghum, millet and maize as staples. He also indicated that during that time the meal pattern was two meals per day and other foods consumed were green leafy vegetables and beef when cattle are slaughtered for ceremonial occasions. This has, however, changed over time with the meal pattern now comprising of three meals per day (Gresse, 1991; MacIntyre, 1998 and Labadarios *et al.*, 2000). The NFCS also found the main meal pattern to be that of three meals per day with 44% of children having in-between meals and 31% without in-between meals. The results from the North West Province however, showed a slight deviation from this norm with a meal pattern of two meals per day with in-between meals observed in 20% of the children (Labadarios *et al.*, 2000).

These recent studies (Gresse, 1991; MacIntyre, 1998; Labadarios *et al.*, 2000) also observed the shift from sorghum and millet as staple to maize meal. The change was attributed to the fact that maize crops were more resistant to disease and produced a greater yield and required less labour (Hunter, 1979; Walker, 1996). Maize meal has remained as a staple because this study observed maize to be the most commonly consumed staple. All the households used maize as a staple as compared to 93% in the National Food Consumption Survey.

The maize meal was usually eaten with milk, pilchards, soup and sometimes meat. The low consumption of meat could be indicative of availability and the economic status of the population which was found to be low (Tladinyane, 2003). The most common source of protein was pilchards (tinned fish), which is cheap and also convenient to store as it does not require refrigeration. From the socio-demographic information, the majority of households did not own refrigerators. This is a further indication that the study population was economically disadvantaged and thus had very limited choices in terms of food. Children who attended the crèche also could eat the soya mince which is normally given for free by government to community based crèches.

The most common vegetables were potato and a relish of tomato and onions. This was also observed by Franz (1971), Gresse, (1991) and ManIntyre (1998). This could be an indication of availability since Oukasie is situated near the commercial farms of Brits known for producing potatoes, onions and tomatoes. These vegetables are, therefore, readily available and are also affordable. Gresse (1991) found that sugar and oil are usually added to these vegetables to give taste. Potatoes are usually mixed with other foods and vegetables as was found in this study.

The dietary patterns indicated that the study population is in transition due to urbanisation. The progressive phenomenon of urbanisation has been found to have a profound effect on the diets, nutrition and health of the population. This is mainly due to the accompanying social, cultural and economic changes (Drewnowski & Popkin, 1997). In South Africa, the nutrition transition has resulted in reduction of diversity of foods which ensured nutritional adequacy to a diet limited to refined carbohydrates increased fat and vegetable intake (Kuhnlein & Receveur, 1996). The diet of children in this study was characterised by limited fruit intake mainly due to unavailability and cost as well as a limited variety of vegetables. This is in contrast with the rural life where wild vegetables were readily available (Franz, 1971). Similarly, with pilchards and soya only the children who attended the crèche had the luxury of eating a fruit in their diet which was mainly an apple or a banana. This leaves

children whose families cannot afford the monthly crèche subscription at a disadvantage because they do not have access to high quality protein in their diets. The interrelationships of these factors are illustrated in Figure 5.2.

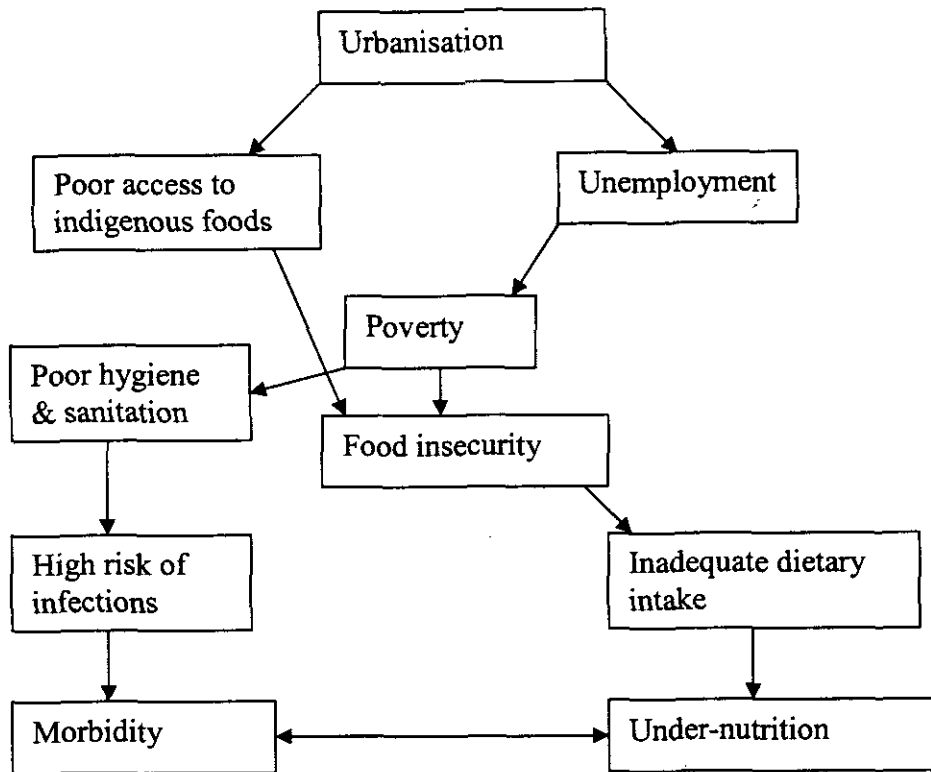


Fig. 5.2 A flow chart of the development of undernutrition in the study population

In summary, according to the UNICEF's conceptual framework, the households in the study population had the following determinants:

- At basic level the households are financially poor and underlying determinants like care and food security were present. This can be regarded as the main determinant of under-nutrition in the study population.

- Another prominent underlying determinant was hygiene practices which can have a bearing on the health of the child as well as poor intake due to lack of appetite. This could be regarded as secondary to the above basic determinant.
- The educational level of the mother might have also played a role.
- Inadequate diets were the obvious immediate determinant as indicated in 5.4.
- This, as already suggested, could be due to the basic determinants of lack of finances and the underlying determinants of food insecurity.

5.5 CRITICAL EVALUATION OF THE STUDY

5.5.1 *The problem*

In order to recap the problem of micronutrient deficiency it can be summarised as follows:

- Iron: two billion people are affected by iron deficiency, that is. ~ 35% of the world population. In developing countries, 51% of children under the age of four years, 40% of all women and 51% of pregnant women are affected.
- Vitamin A: Among children under the age of five years, 250 million suffer from moderate to severe vitamin A deficiency. Vitamin A deficiency is a public health problem in over 70 countries. Three million children have some form of vitamin A related eye disease varying from night blindness to irreversible partial or total blindness.

5.5.2 *What can be done and what is available?*

There are four well known strategies that can be implemented successfully to prevent and control these deficiencies. These are food fortification, supplementation, dietary improvement and public health measures. These strategies usually work effectively if they are combined since none of them is a “magic bullet”. The strategies need to be designed and tailor-made for specific regions or countries. The complementary effects of the strategies are depicted in **Figure 5.3** below.

From the results of this study, it seems that the fortification of maize meal yielded positive results. Fortification of maize was effective in improving the haematological and vitamin A status of underweight and stunted children. Fortification offers an opportunity to deliver micronutrient-rich foods to a large population. Gram for gram, minute amounts of these micronutrients are added to commonly consumed foods and can aid in eliminating micronutrient malnutrition in both industrialized and developing countries. Fortification cannot reach all deficient people, but the bulk of the affected population can be reached, and by doing so, releasing huge health, economical, labour and educational benefits to the developing world. The World Bank estimates high returns from investment in the elimination of micronutrient deficiency (Micronutrient Initiative, 1995).

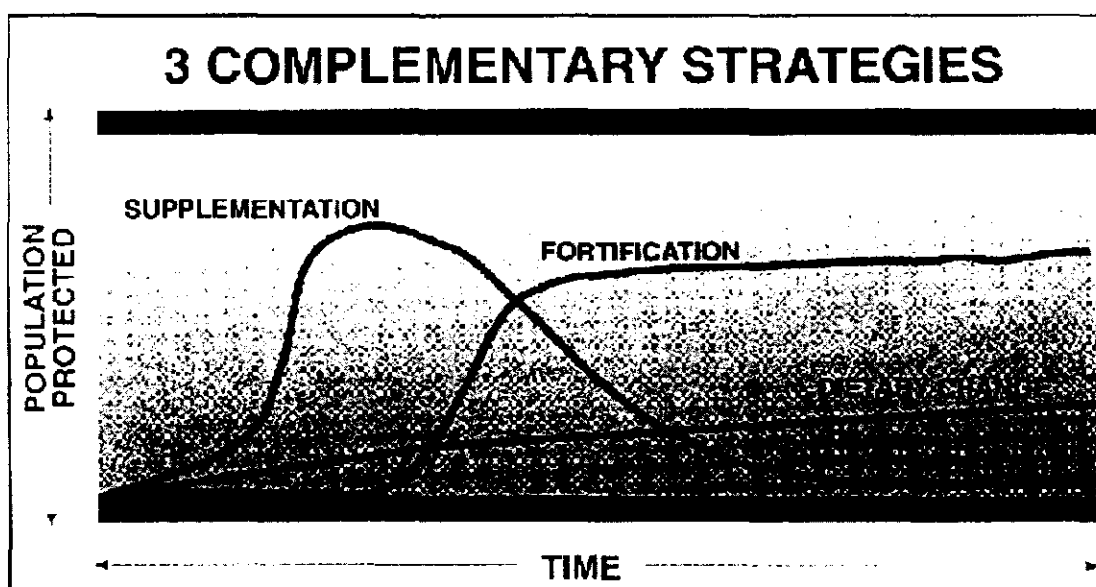


Figure 5.3 The complementary effects of the strategies of combating micronutrient deficiency (Micronutrient Initiative, 1995)

In this study, a staple food, namely maize meal, was fortified mainly because it is consumed by the vast majority of the South African Population (Labadarios *et al.*, 2000). This notion was confirmed by the forum on food fortification (Micronutrient Initiative, 1995) in that they suggested that “Food vehicles for fortification should be selected through a process of careful market research that

identifies foods that are consumed by the majority of the population, are affordable to those most in need, and respect both political and cultural sensitivities and consumer preferences.” If one considers maize meal, it is consumed on average by 93% of the affected population and it is a vehicle of choice by the population as well as government (Labadarios *et al.*, 2000).

The fortification of cheap staples results in a wider dissemination of micronutrients, especially to those that are poor. The value added commodities like snacks and condiments can be used for isolated cases where the affluent portions of the population are affected. It must, however, be reiterated that fortification cannot be effective on its own, but it should be in combination with the other two methods as well as selected public health measures like the improvement of food security.

5.5.3 *What should happen in South Africa*

The time for action is now, the benefits for intervention are enormous and the overall costs are low. South Africa is in the process of preparing legislation on fortification. The outcome of this study should add more drive to the process. This study seems to suggest that maize is a good vehicle for fortification. For the fortification to be successful, all stakeholders need to be involved, namely Government, non-governmental organisations, food and pharmaceutical industries, funding agencies and the consumer. The relationship of the stakeholders is depicted in **Figure 5.4** below.

The solutions are available, industry has the technology, and the solutions are also feasible and affordable. The most important aspect is that government should be committed. The maize and the pharmaceutical industries should now be engaged in discussions to facilitate the implementation of the envisaged programme. It will also be important to sensitise the affected community about the benefit of consuming fortified products, as well as a simple means of identifying them.

This study on a small number of children indicated that maize meal is a good choice for fortification in South Africa. The government's paper on fortification should be supported by nutrition practitioners to facilitate the roll-out of the programme.

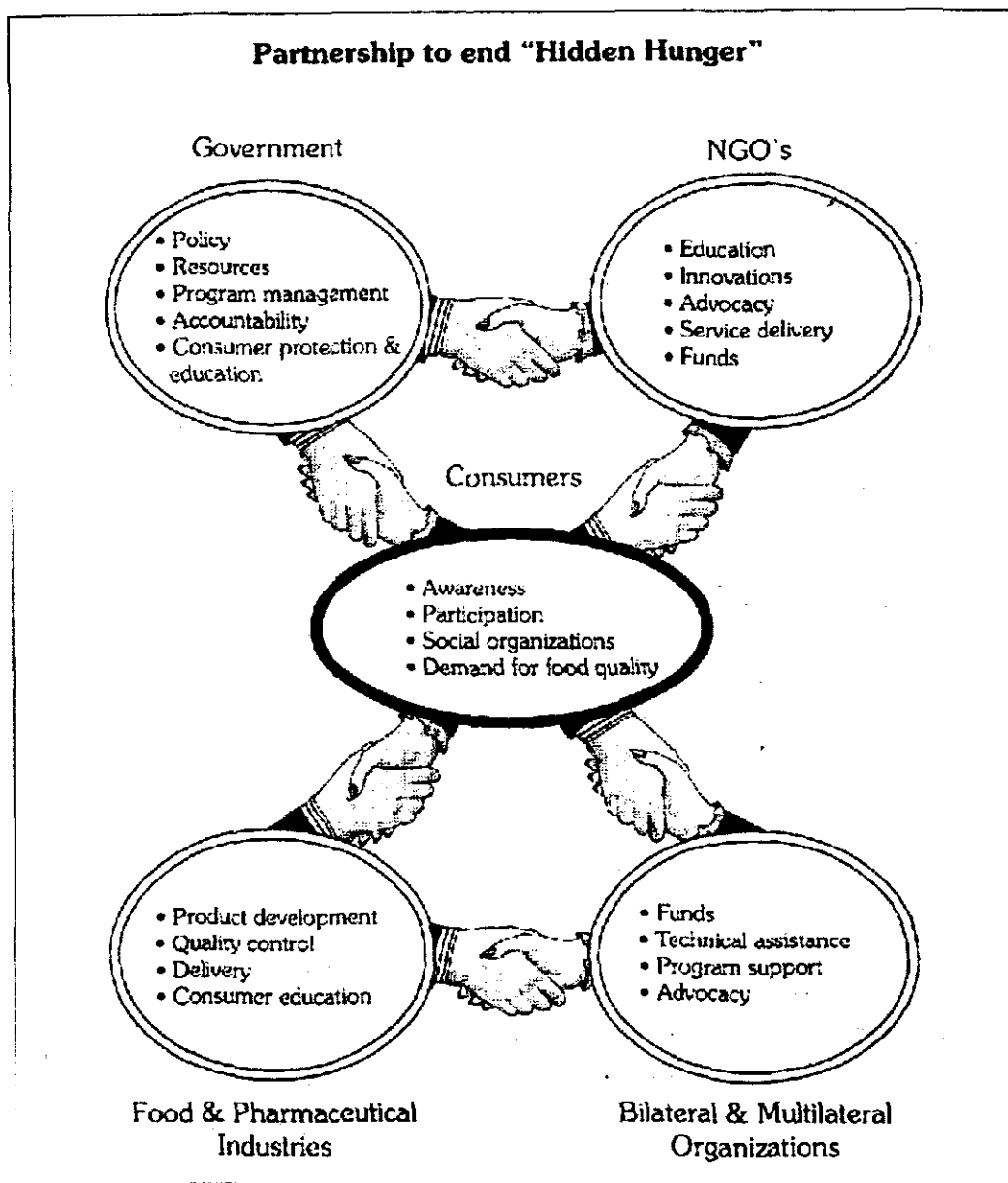


Figure 5.4 The relationship among stakeholders in the implementation of fortification (Micronutrient Initiative, 1997)

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 SALIENT FINDINGS

The main aim of the study was to assess the effectiveness of vitamin fortification of maize meal on the nutritional status of previously undernourished children aged 1 to 3 years residing in Oukasie, Brits.

The salient findings of the study were:

- Food insecurity accompanied by poverty and unhygienic practices, and probably an inadequate diet are still the major underlying determinants of under-nutrition in this example of a developing area of South Africa.
- In the intervention study, both experimental and control groups experienced an improvement of weight and height. However, the experimental group had on average an increase in weight gain of 2.2kg above the expected weight gain of 2.4kg for children in the age group, while the control children only gained the expected 2.0kg in weight. No difference in height gain were observed between the two groups, although both groups showed significant increases in height.
- The prevalence of anaemia is high in this community, 54% and 57% at baseline for the experimental and control group respectively.
- The experimental group experienced a statistically significant improvement in haemoglobin from baseline to end.
- The experimental group experienced a marked reduction of children with anaemia from 54% to 40% whilst the control group had an increase from 57% to 68%. This means that the vitamin fortification of the maize meal probably had a positive impact on the iron status of the children in the experimental group.

- Both experimental and control groups exhibited a statistical significant reduction in haematocrit.
- The change from baseline to outcome for haematocrit was significantly different between the experimental and control groups. This indicated that the fortification of maize probably arrested the reduction of haematocrit in the experimental group.
- The prevalence of vitamin A deficiency was high in this community, 67% and 29% at baseline for the experimental and control groups respectively.
- Both experimental and control groups experienced a statistically insignificant increase in serum retinol.
- 60% of children in the experimental group had an increase in serum retinol level as compared to 35% from the control group.
- The control group had a statistically significant reduction in serum retinol binding protein.
- The change from baseline to outcome for retinol binding protein was significantly different between the experimental and control groups. This was an indication that the fortification with vitamin A arrested the decline of serum retinol binding protein in the experimental group.
- The change in serum retinol significantly correlated with the change in haemoglobin for both groups, confirming a relationship between vitamin A and iron status. The results further indicate that vitamin A fortification had an impact on the haemoglobin levels, even when iron was not included in the fortification regime.
- Children with lower vitamin A status (serum retinol levels) showed a better responses to the fortification intervention than those with higher vitamin A status at baseline.
- Maize meal is a suitable vehicle for vitamin A fortification since all these malnourished children regularly consumed maize porridge and because between 59 and 79 % of the vitamin A is retained after cooking.

It can therefore be concluded that vitamin fortification of maize yielded some positive outcomes on the nutritional status of previously undernourished children aged 1 – 3 years.

Scientifically the number of children in each group should have been at least 50 for adequate “power” of the statistical analysis. From the socio-demographic analysis, the undernourished children were found to be economically disadvantaged when they are compared with their “normal weight” counterparts. (Tladinyane, 2003). Their hygiene and sanitation score was also low as compared to children who were well nourished.

6.2 RECOMMENDATIONS

1. The mandatory fortification of maize meal in South Africa should be supported as one means of improving the nutritional status of children who are under-nourished.
2. The improvement of food security in Oukasie through various means like job creation, subsistence farming as well as the overall empowerment of women in the area, needs urgent attention.
3. Iron should be included in any fortification regimen that will be implemented by government.
4. Other intervention strategies of eradicating vitamin A and iron deficiency should be employed in Oukasie.
5. More children should be included in studies similar to this one in order to improve the power of the statistical analysis. However, there seem to be no need to prove if maize meal fortification does improve the nutritional status of children who were previously undernourished, since this study demonstrates positive outcomes even when small numbers and a limited number of variables measured.

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APPENDIX 1

INFORMED CONCENT : MAIZE FORTIFICATION PROJECT

Title of the project: The effectiveness of vitamin A, folic acid, riboflavin, niacin, thiamin and vitamin B6 fortification of maize meal to improve the nutritional status of children aged 1 – 3 years residing in Oukasie, North West Province.

Name of child :

I, (Full names) the parent to child named above, hereby consent that he/she may participate in the maize fortification project. I understand the following will be done: taking blood, measuring (weight, height & MUAC), clinical signs and enquiring about what the child is eating.

Signature

Date

Relationship

Address and telephone number:

.....
.....
.....
.....

Office use:

APPENDIX 2

3. Marital status of mother: **(Tick one)**

Unmarried	1
Married	2
Divorced	3
Separated	4
Widowed	5
Living together	6
Other (please specify)	7

Tick one block only for every question:	Father	Mother	Sibling	Grandma	Grandpa	Aunt	Uncle	Cousin	Friend	Other
4. Who is responsible for food preparation in the House	1	2	3	4	5	6	7	8	9	10
5. Who is mainly responsible for feeding/serving the child?	1	2	3	4	5	6	7	8	9	10

Now decide on the following:

6. Type of dwelling: You can tick more than one Block if necessary	1	2	3	4	5
	Brick, Concrete	Traditional Mud	Tin	Plank, Wood	Other Specify:
7. Number of people sleeping in the house for at least 4 nights per week?					
8. Number of rooms in house (excluding bathroom, toilet and kitchen, if separate)					
9. Where do you get drinking water most of the time? (Tick one)	1	2	3	4	5
	Own Tap	Communal Tap	River, Dam	Borehole, Well	Other (Specify)
10. What type of toilet does the child use at home? (Tick one)	1	2	3	4	5
	Flush	Pit	Bucket, Pot	VIP	Other (Specify)

11. What fuel is used for cooking most of the time? (You can tick more than one)	1	2	3	4	5	6
	Electric	Gas	Paraffin	Wood/Coal	Sun	Other specify

Tick one box only:

12. Does the child's home have a working: (i) Refrigerator/Freezer	1	2	3	4
	Fridge	Freezer	Both	None
(ii) Stove	1	2		
	Yes	No		
(iii) Microwave	1	2		
	Yes	No		
(iv) Hot Plate	1	2		
	Yes	No		
(v) Radio or Television	1	2	3	4
	Radio	TV	Both	None

Now ask questions about:

13. Mother's employment status (Tick one only)	1	2	3	4	5
	Housewife By choice	Unemployed	Self-Employed	Wage-Earner	Other Specify
14. Father's employment status (Can tick more than one)	1	2	3	4	5
	Unemployed	Self-Employed	Wage-Earner	Retired by Choice	Other Specify

15. Household income per month (including wages, rent, sales of veges, etc. state grants).
(Tick one only)

None	1
R100 – R 499	2
R 500 – R 999	3
R 1000 – R 2999	4
R 3000 – R4999	5
Over R 5000	6
Don't know	7

16. Is this the usual income of the Household? (Tick one box only)	1	2	If NO, what other income is available, specify:		
	Yes	No			
17. How many people contribute to the total income? (Tick one only)	1	2	3	4	5
	1 person	2 persons	3-4 persons	5-6 persons	More than 6 persons
18. Is this more or less the income that you had over the past six months? (Tick one only)	1	2			
	Yes	No			

19. How much money is spent on food weekly? **(Tick one only)**

R0 - R49	1
R50 - R 99	2
R 100 - R149	3
R 150 - R 199	4
R 200 - R249	5
R 250 - R 299	6
R 300 - R 349	7
R 350 - R 399	8
Over R 400	9
Don't know	10

APPENDIX 3

CHILD CARE QUESTIONNAIRE

Subject Number Interview Date

(All information in this questionnaire is confidential)

Child's Name: _____ Gender: M F

DOB: _____ Age: _____ Religion: _____

Address: _____ Ethnic group: _____

_____ Tel: _____

1. NUTRITION KNOWLEDGE QUESTIONS (Tick one block only)

1.1 When should breastfeeding be initiated?

Immediately after birth (< 1 hour)	1
1 hour after birth	2
2 - 3 hours after birth	3
4 - 8 hours after birth	4
A day after birth	5

1.2 What are you supposed to give your baby immediately after birth (within 1 hour)?

Soft pap	1
Water	2
Breast milk	3
Bottle milk	4
Nothing	5

1.3 How many times should you breast feed per day?

On demand	1
1-3 times a day	2
4-6 times a day	3
7-8 times a day	4

1.4 How long should the child be breast fed at time?

5-10 minutes in each breast	1
10-20 minutes in each breast	2
30 minutes in total	3
Until the baby is satisfied	4
Other (please specify)	5

1.5 At what age were you told to feed your baby any of the following?

FEED	FROM BIRTH	DAYS	MONTHS	N/A
1.5.1 Water				
1.5.2 Other Milk product				
1.5.3 Soft food				
1.5.4 Other (please specify)				

1.6 When are you supposed to stop breastfeeding your child?

1 - 2 months	1
3 - 4 months	2
5 - 6 months	3
7 -12 months	4
1 - 2 years	5
Above 2 years	6

1.7 What should you use to give your child milk formula?

Bottle	1
Cup	2
Spoon	3
Don't know	4
Other (please specify)	5

1.8. How many times per day should you give your child food?

On demand	1
1-3 times a day	2
4-6 times a day	3
7-8 times a day	4

1.9. Should you give in-between meals?

YES	1
No	2

If Yes, how many times?

Once	1
Twice	2
3 times	3
Other (Please specify)	4

1.10. Should you add anything to your child's porridge to make it more nutritious?

Yes	1
No	2

If Yes, what should you add?

Sugar	1
Oil/Margarine	2
Eggs	3
Milk (Fresh/Powder)	4
Peanut butter	5
Gravy	6
Meat/Fish/Poultry	7
Other (Please specify)	8

2. EDUCATIONAL LEVEL

2.1 What is the highest standard passed? (mother)

Grade 1 - Grade 4	1
Grade 5 - Grade 7	2
Grade 8 - Grade 10	3
Grade 11 - Grade 12	4
Post Matric	5

2.2 What is the highest standard passed? (caregiver)

Grade 1 - Grade 4	1
Grade 5 - Grade 7	2
Grade 8 - Grade 10	3
Grade 11 - Grade 12	4
Post Matric	5

3. FAMILY SUPPORT

3.1 Is there anybody besides you who takes care of the child?

YES	1
NO	2

If Yes who is the main caregiver? (Tick one)

Father	1
Grandparent	2
Uncle/aunt	3
Cousin/nephew	4
Friend	5
Other (please specify)	6

	1	2
	Yes	No
3.2. Can the caregiver manage without instructions?		
3.3. Does the child's father spends time with the child?		
3.4. Does the child's father participate in household chores?		
3.5. Do the older siblings spend time with the child?		
3.6 Do the older siblings participate in household chores?		

**4. CONTROL OF FAMILY FINANCIAL RESOURCES
(You may tick more than one block)**

	1	2	3	4	5
	Father	Mother	Siblings	Other	Don't know
4.1 Who controls the income earned in the family?					
4.2 Who decide how much is spent on food?					
4.3 Who decides on what food is bought?					

5. WORKLOAD AND TIME AVAILABILITY

5.1 How many hours in a day do you spend in:

	1	2	3	4	5
	< 1 hour	1-2 hrs	3 - 4 hrs	> 4 hrs	N/A
5.1.1 Fetching water					
5.1.2 Gathering wood					
5.1.3 Preparing food					
5.1.4 Doing the laundry					
5.1.5 Cleaning the house					
5.1.6 Other					

5.2 How many hours in a day do you spend in:

	1	2	3	4	5
	< 1 hour	1-4 hrs	5-8 hrs	> 9 hrs	N/A
5.2.1 Agricultural labour					
5.2.2 Self employment					
5.2.3 Employment					
5.2.4 Activities for additional income					

6. HYGIENE PRACTICES
(Now observe the following and tick appropriately)

6.1 Appearance of the house

	1	2	3
	CLEAN	AVERAGE	DIRTY
6.1.1 Kitchen floor			
6.1.2 Kitchen wall			
6.1.3 Pots			
6.1.4 Plates			
6.1.5 Cutlery			
6.1.6 Stove			
6.1.7 Table			
6.1.8 Water storage			
6.1.9 Playing area			

6.2 Appearance of the mother

	1	2	3
	CLEAN	AVERAGE	DIRTY
6.2.1 Hair			
6.2.2 Face			
6.2.3 Hands			
6.2.4 Feet			
6.2.5 Teeth			
6.2.6 Clothes			

6.3 Appearance of the child

	1	2	3
	CLEAN	AVERAGE	DIRTY
6.3.1 Hair			
6.3.2 Face			
6.3.3 Hands			
6.3.4 Feet			
6.3.5 Teeth			
6.3.6 Clothes			

APPENDIX 4

ANTHROPOMETRY

Now you have to weigh and measure the child. Take three measurements and record the average.

Weight

--	--	--

 ,

--

 kg Height

--	--	--

 ,

--

 cm.

In the case where you weigh the child with the mother/caregiver, use the following tables:

Weight of Mother/Caregiver and Child

 ,

 kg

Weight of Mother/Caregiver only

 ,

 kg

Difference

 ,

 kg

Now you have to weigh and measure the Mother/ Caregiver. Take three measurements and record the average.

Weight of Mother/Caregiver

 ,

 kg

Height of Mother/Caregiver

 ,

 cm

APPENDIX 5

ALL THE INFORMATION IN THIS QUESTIONNAIRE WILL BE HANDLED WITH THE STRICTEST CONFIDENTIALITY

DIETARY INTAKES

24 HOUR RECALL

NAME OF CHILD
CODE NUMBER

DATE
DAY OF RECORD

1. Did the child drink anything when he/she woke up yesterday?

1. Yes
2. No

What he/she have?
.....
.....

How much?
.....
.....

2. Did the child eat anything when he/she woke up yesterday?

1. Yes
2. No

What he/she have?
.....
.....
.....
.....

How much?
.....
.....
.....
.....

3. When did the child eat again?

Where?

What did the child eat?
.....
.....
.....
.....

How much?
.....
.....
.....
.....

4. Did the child eat anything before lunch?

1. Yes
2. No

What did the child eat?
.....
.....
.....
.....

How much?
.....
.....
.....
.....

5. Did the child drink anything before lunch?

- | |
|--------|
| 1. Yes |
| 2. No |

What did the child drink?

.....

How much?

.....

6. What did the child eat and drink for lunch?

.....

How much?

.....

7. When did the child eat again?
 What did the child eat?

.....

Where?

How much?

.....

8. Did the child drink anything else before dinner?

- | |
|--------|
| 1. Yes |
| 2. No |

What did the child drink?

.....

How much?

.....

9. What did the child eat/drink for dinner?

.....

How much?

.....

10. Did the child drink anything after dinner before he/she went to bed?

- | |
|--------|
| 1. Yes |
| 2. No |

What did the child drink?

.....

How much?

.....

11. Did the child eat anything after dinner before the child went to sleep?

- | |
|--------|
| 1. Yes |
| 2. No |

What did the child eat?

.....
.....

How much?

.....
.....

12. Was the food eaten yesterday different from the usual?

1. Yes
2. No

If yes how?

.....
.....
.....
.....

13. Did the child take any vitamin tablets or syrup yesterday

1. Yes
2. No

If yes, What did the child take?

How much?

.....
.....

.....
.....

Did the child eat any sweets or chips yesterday?

1. Yes
2. No

What type sweets/chips

How much?

.....

.....

14. Did your child eat or drink anything else not mentioned here?

1. Yes
2. No