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EDITORIAL

Food fortification is increasingly recognized as an effective and long term approach to improving the micronutrient status of large populations. Some studies have shown fortification to be one of the most cost effective methods of reducing micronutrient deficiencies although effective monitoring regulation and enforcement are key to the success of fortification programmes.

Fortification programmes require careful planning to ensure that appropriate food vehicles and fortificants are selected to enhance micronutrient status in the target population. In areas where there is no centralized processing, fortification in small mills or even household level fortification might be considered. All fortification programmes must address quality assurance and safety concerns.

Fortification calls for a multisectoral effort involving the participation of government, private industry, NGO's scientific expert groups and even consumer groups. Advocacy targeted at all of these groups is crucial to the success of a fortification programmes.

Malting characteristics of Tanzania finger Millet varieties

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Abstract

Five millet varieties were collected from five different regions in Tanzania and the malting characteristics and the malt quality assessed. The malting losses, germinative energy, free amino nitrogen and diastatic power ranged between 9.4 – 27.7% and 87.7 – 95.7%, 96 – 102 mg/100 and 34.7 – 45.1 SDU/g, respectively. Muhone variety from Dodoma region (MD) was the best for brewing purposes because of the high diastatic power while Bambare variety from Dodoma was worst. Significant differences ($P < 0.05$) between varieties were observed in germinative energy, free amino nitrogen (FAN) and diastatic power (DP). In millet grains, starch constituted more than three fourth of the grain weight followed by protein, crude fibre, ether extract and ash. Malting caused slight decrease in protein, ash and starch contents while it increased the ether extract, crude fibre and calcium.

Key Words: diastatic power, free amino nitrogen, finger millet, malting

Introduction

Millet is an annual grass that is extensively used in tropical and sub-tropical areas of the world. It is the fifth most important cereal in the world after wheat, maize, rice and barley. Among all millet, pearl millet (*Pennisetum typhoides*) accounts for 40% of the total world production (Kent, 1983). The other common millet are finger millet (*Eleusine coracana*), barnyard millet (*Echinochloa frumentacea*) proso millet (*Panicum miliaceum*), foxtail millet (*Setaria italica*) and teff (*Eragrostis tef*).

In the regions where millet is grown, it is used to prepare several types of food products, some of which are fermented. In East African countries, among other uses, millet is malted and used to brew various traditional beers (Ekundayo, 1969). Some of the popular traditional beers are known by their local names, e.g. mbege, ntulu, burra, irusu, and kindi. Malting is simply a biochemical modification of the grain to produce malt that has improved nutritional quality than normal grain. During malting the grain develops amylolytic enzymes, which hydrolyse starch to fermentable sugars. Traditional malting techniques include 24 hours steeping by continuous immersion of the grain followed by 2-3 days germination in 5-10 cm thick layers under damp burlap bags. The green malt is subjected to solar dehydration

for one to two days (25-30°C). The other major uses of malted millet in Tanzania are preparation of non-alcoholic beverages and weaning foods. Some advantages brought about by malting include the improvement of grain nutritional quality by reducing the antinutritional factors responsible for poor digestibility and increasing palatability of the grains. Use of millet to replace expensive imported barley malt in beer brewing has been tried (Skinner, 1976, Nout and Davies, 1982). Sorghum has substituted barley malt in the production of lager beer in Nigeria (Koleoso and Olatunji, 1988). No such attempt has been made in Tanzania finger millet varieties. Finger millet has proved excellent in production of traditional beer such as mbege (Shayo et al, 1997). It is from this information that its potential in brewing lager beer is anticipated. The aim of this paper is, therefore, to analyse the malting characteristics of Tanzania finger millet varieties with the view to determine their suitability in brewing of lager beer.

Materials and Methods

Materials

Five millet varieties were collected from five regions in Tanzania. The names of the samples and the regions of origin are indicated in Table 1.

Table 1. Names of millet varieties and their regions of origin

Local names ^a	Abbreviation ^a	Source
Muhone	MD	Dodoma
Bambare	BA	Arusha
Ukusi	US	Singida
Mbeke	MK	Kilimanjaro
Ulyo	UR	Rukwa

^aLocal names from the growing areas

^bThe first letter represents the local name of the millet variety while the second is the first letter of the region of origin.

Methods

Micro-malting

The grains were cleaned by a combination of hand picking and water floatation. Broken and holed grains, stones, and other debris were rejected. After hand

Table 2 Chemical composition (% dry basis) of millets before and after malting

Variety	Protein		Ether extract		Crude fibre		Ash		Starch		Calcium		Phosphorus	
	BM ^b	AM ^c	BM	AM	BM	AM	BM	AM	BM	AM	BM	AM	BM	AM
Mk	8.91	8.28	3.12	3.40	3.26	3.44	2.9	2.42	82.7	81.4	0.33	0.41	0.24	0.21
BA	12.5	11.8	3.20	3.30	2.05	2.59	2.73	2.44	80.1	79.3	0.01	0.09	0.35	0.27
MD	10.7	10.4	3.05	3.00	2.14	2.42	3.12	2.90	81.4	80.7	0.17	0.19	0.45	0.37
US	10.9	10.5	3.31	3.39	2.50	2.84	2.61	2.41	81.1	80.4	0.34	0.42	0.12	0.09
SR	10.8	10.5	3.17	3.34	2.14	2.32	2.91	2.65	81.5	80.6	0.03	0.05	0.35	0.32
Mean	10.7	10.3	3.17	3.31	2.42	2.67	2.86	2.56	80.9	80.6	0.176	0.232	0.301	0.254
SD	1.27	1.26	0.09	0.12	0.50	0.45	0.20	0.19	0.89	0.84	0.158	0.915	0.126	0.108
Range	3.5	3.52	70.2	0.30	0.45	0.45	0.51	0.49	2.48	2.14	0.33	0.37	0.33	0.28

^a Means and SD of four independent determinations.

^b Before malting.

^c After malting.

picking, the grains were poured into a vessel containing water and the floater were removed and discarded. Samples (0.5 kg) of the dried clean grains were put in aluminium pot and steeped with excess tap water for 48 hours. The grains were then germinated at room temperature for 2 days. The germinating grains were turned and moistened twice a day. At the end of 48 hours of germination, the wet grains were dried by spreading them in an oven at 40°C for 24 hours as described by Dewar et al. (1995).

Chemical Analyses

Five samples of millet and malt obtained from these samples were analysed for proximate composition. Protein, fat and ash were determined using the AACC methods (1983). Crude fibre content was determined as described by Osborne and Voegt (1978). Starch content was calculated by difference. Calcium and phosphorus were determined using the AOAC (1995) methods number 944.03 and 948.08, respectively. Malting losses were determined as described by Novellie (1962). Germinative energy (GE), diastatic power (DP) and free amino nitrogen (FAN) were determined as described by Dewar et al. 1995.

Results and Discussion

The chemical compositions of millet before and after malting are summarised in Table 2. As a general observation, starch content appeared high in millet grains compared to the other nutrients. According to Dendy (1995), starch is the most abundant chemical component, where it forms one half to three fourth of the whole grain. The decrease in starch content in the malt was due to hydrolysis by native enzymes (α - and β -amylases) during germination resulting in increase in reducing sugars (Dewar et al. 1995). Malting also caused significant reduction ($P < 0.05$) in

protein and ash contents. The decrease in protein as a result of malting was due to hydrolysis of native proteins to low molecular weight proteins or peptides and increase in enzyme activity (Hussian et al. 1966).

Ether extract and fibre slightly increased during malting. The increase in calcium content after germination is supported by Perrisse et al. (1966) who observed similar trend during malting of sorghum. The decrease in phosphorus content is a result of it being used up in the metabolic processes during germination. The results on malting losses are summarised in Table 3. The data obtained agree with those previously reported by Morral et al. (1986) that the malt losses of millet range from 2.5 – 17%. MD and UR varieties had higher values than the reported ones. This was due to the differences in the amount of saccharifying enzymes in the growing embryo, which induced growth of roots and shoots and hydrolysed starch (Novellie, 1962).

Table 3 Quality attributes of millet malt^a

Variety	Malting losses	Germinative		
		energy	FAN	DP
	%	%	mg/100g	SDU/g
MK	15.2	87.7	108.0	40.9
BA	9.4	94.0	96.4	34.7
MD	27.4	93.3	102.2	45.1
US	12.6	92.0	102.3	41.6
UR	19.9	95.7	106.7	43.3

^a Values are means of two independent determinations.

The germinative energy values for the grains are reported in Table 3. There was significant difference ($P < 0.05$) in germinative energy between varieties. The results conform with those of Dewar et al. (1995) who reported that after 72 hours from the start of the

germination, at least 90% of the millet grain should have germinated for it to be accepted for malting purposes. Based on this criterion, it is apparent from the results that all varieties except MK qualify for use as malting material. Other factors being favourable, BA and US varieties would be economically more favoured for malting because of the relatively lower malting losses. All the varieties did not attain 100% germination under the conditions of study and the UR variety exhibited the highest (95.7%) germinative energy. The variety with the lowest germinative energy was MK (87.7%). Low germinative energy is sometimes associated with chemical treatment in silos during storage due to age (Dendy, 1995) and poor moisture uptake during steeping (Hofmeyr, 1970, Daiber, 1975).

There was significant difference ($P < 0.05$) in free amino nitrogen between the five-malted millet varieties. Morral et al. (1986), found that the value for FAN in millet malt was 87 – 155 mg/100g. The obtained results (Table 3) ranged from 96 – 108 mg/100g, thus conforming to the reported values. MK variety had highest FAN. The FAN content of the malt is the product of both the catabolic processes, which degrade the storage proteins into peptides and amino acids, as well as the anabolic processes that synthesise them into new proteins in roots and shoots. Adequate FAN content is necessary to support yeast growth during fermentation.

There are simple activities resulting from simultaneous action of α - and β - amylases. They are responsible for generation of extract and fermentable extract during the conversion of starch to alcohol. There is no universally accepted specification for sorghum and millet malts. However, a minimum specification of DP of 28 SDU/g for malt for industrial sorghum or millet beer brewing appears to be widely used (Dewar et al, 1995). The DP obtained in all samples (Table 3) was enough to make them suitable for malting purposes. The Analysis of variance (ANOVA) test showed that there is a significant difference ($P < 0.05$) DP between the millet varieties. This is due to the fact that each variety had its own ability to produce gibberelins, the hormones which during malting, are produced in the germ of the grain and diffuse into the endosperm and the aleurone layer. In the endosperm they induce the synthesis of α - amylase (Dendy, 1995). MD variety showed a stronger enzyme activity than the other varieties as it had greater DP. DP is widely affected by germination time, temperature and moisture.

Conclusions and Recommendations

The results show that all the varieties studied have most of the important chemical constituents in substantial amounts. Malting caused decrease in starch and protein as a result of transformation of starch to sugars and FAN

from proteins hydrolysis. These products are essential for beer making. Therefore, malt produced from these millet varieties is of high nutritional quality for brewing and food use. All the varieties used in this study displayed a high potential for malting. This is because they both produce the acceptable germinative energy of more than 90% except MK variety. The MD and UR seem to be better choices for malting and brewing as they produce malts of high diastatic power. The results obtained could be used as a base for further studies on various uses of millet varieties as malt.

Since there are so many millet varieties in this country and that most of them have not been studied in the context of brewing and food, there is urgent need for their screening. This will enable promotion of those with promising potential for the end uses.

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Effect of Germination on Total Phenol, Tannin Type Phenols and Tannin Phenol Content of Sorghum, Cow Peas and Green Grams

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Abstract:

The effect of germination on total phenols, tannin type phenols and non-tannin phenol content of high-tannin sorghum, cowpeas and green gram grains was investigated using the Prussian Blue test method. The result indicated that germination has a significant ($P < 0.01$) reduction effect on total phenols, tannin and non-tannin phenol content of sorghum. Although germination showed a moderate reduction of phenol content of cowpeas, there was no significant ($P < 0.05$) reduction of phenol content in green grams as a result of germination. Reduction effect was higher in tannin type phenols than non-tannin phenol content in sorghum, cowpeas and green grams. Reducing effect was rapid during the first 48 hours of germination and continued at slower rate up to 72 hours of germination. Germination of grains is among popular traditional processing methods, it is simple and is commonly practised in the rural community. This process can, therefore, be applied as an intermediate grain treatment to reduce the antinutritional effect of phenolic compounds like tannins in some grains, particularly the high-tannin varieties. Consequently, this will improve their nutritive value.

Key words: Phenol compounds, tannin, germination.

Introduction

The presence of phenolic compounds like tannin in food plants like cereals and legumes is wide spread (Wang et al, 1997; Mayer and Harel, 1997; Udayasakhara-Rao and Desothale, 1987). These compounds are secondary metabolites, which play an important role of defence mechanism in the plants. They defend the plants against herbivores, insects, bacterial and fungal spoilage.

Polyphenols in many edible plant products have received increasing attention as a result of their influence on the nutritional and aesthetic quality of foods, biochemical and physiological functions, and also pharmacological implications (Haslam and Lilley, 1988; Salunkhe et al, 1990; Hirose et al, 1990; Zhi et al, 1994; Yen and Chem, 1995; Unten et al, 1997). The antinutritional effect of polyphenols, like tannin are mainly related to impaired availability of proteins (Hagerman, 1992; El-Khalifa and El-Tinay, 1994), minerals like iron (Wang and Kies, 1991; Aldrian et al., 1997) and interfere with enzyme and

vitamin functions in the body (Suchertat, 1975) they have been reported to possess some toxigenic properties (Singleton, and Kratzer, 1973; Suchertat, 1975). Levels between 0.2 and 2 percent of condensed tannins in the diet have been suggested by several investigators to cause depressed growth on experimental animal (Despande et al, 1984; Salunkhe et al, 1990). Siegenberg et al. (1991) showed that adding 12 mg tannic acid into a meal decreased iron absorption in human by one third and 50 mg tannic acid reduced absorption by almost 70%. Similar results were earlier reported by Brune et al. (1989) and the inhibitory effect was related to the galloyl group of tannic acid.

Vegetable phenolic compounds, like tannins occur in relatively high concentration in some foods, which may constitute the main staples in some areas of the world. Such foods include sorghum varieties, millet and variety of legumes, which serve as main meals in most of developing countries including Tanzania.

Due to the antinutritional and toxic effects of phenol compounds, several attempts have been made either trying to remove these compounds from the food materials or otherwise render it harmless. Germination process is among the processing methods, which has been reported to have reducing effect on phenolic compounds (Obizoba and Atii, 1991; Sharma and Ehgal, 1992; Udayasakhara-Rao, 1995; Chau and Cheug, 1997). The method is simple and applicable in the community

This investigation was undertaken to study the effect of germination on the phenol content in high-tannin Sorghum (Udo), cowpeas and green grams classified as total phenol, tannin related phenol and non-tannin compounds and to see which class of phenol compounds was mostly affected by such processing.

Materials and Methods

Food Material and grain treatment

Food grains of high-tannin sorghum-udo cowpeas and green grams were purchased from Dar es Salaam and Dodoma local markets in Tanzania. Fresh dry clean (with damaged seeds and foreign particles removed) food grains were soaked in distilled water at a ratio of 1:5 grain: water (w/v) overnight. The samples were then drained, spread on a white tissue paper (plastic-backed) placed on a white

bench and allowed to germinate for 36, 48 and 72 hours at room temperature with an occasional spray of distilled water. Untreated sample were left as a control. At the end of treatment, all samples were freeze-dried, hammer-milled and packed in plastic containers and stored until they were needed for analysis of phenolic compounds.

Analysis of Tannin in Food Materials

A 60 mg of the grounded grain (flour) was weighed. To this sample, 5 ml of the extraction

solvent (water/salt solution) was added and the mixture homogenized by shaking vigorously using laboratory shaker for one minute. The mixture was centrifuged for 10 minutes at 5,800 rpm. and the clear solution was collected. The remainders in the test tubes were rinsed by 5 ml of the solvent with vigorous shaking, centrifuged for 5 minutes at the same speed and the clear solution was collected again and added to the first (making up a total of about 10 ml). The volumes were raised to 50 ml by distilled water in a volumetric flask and the Prussian blue reagents were added as described below. Optical density (absorption) was measured at 720 nm after 10 minutes of incubation at room temperature. The result were expressed as gram of catechin equivalent (C.E) per 100 g sample.

The Prussian Blue Test Method Principle

The Prussian Blue Test method has been suggested by Price and Butler (1977) as a modification of various calorimetric procedures which utilize ferric chloride as a principle reagent. The method is based on the reducing power of the hydroxyl groups of the phenolic/tannin compounds. Reagents used were 0.1M FeCl₃ in 0.1N HCL and 0.008MK₃ Fe (CN)₆ in distilled water. The ferric iron is reduced to ferrous iron by phenols/tannins to form a ferricyanide-ferrous colour complex commonly known as Prussian blue. The colour intensity was measured at 720 nm (the red end of the spectrum). The solution, however, appeared green because of the blue colour of untreated ferricyanide. The changes of colour produced by these reagents were easily distinguished visually, and, therefore, gave the method a credit for applicability in the field routine work. Total phenolic compounds were obtained by using water extraction of the samples, non-tannin phenols by aqueous salt solution and tannin type phenols by difference.

Results and Discussion

Germination had a variable effect on content of phenolic compounds in sorghum, cowpeas and green grains (Table1)

Table 1: Effect of germination at different time on content of phenolic compounds in sorghum, cowpeas and green grams

Germination time (h)	Phenolic content (mg catechin equivalent (C.E) per 100 gram sample)								
	Sorghum			Cowpeas			Green grams		
	Total phenol	Non tannin	Tannin phenol	Total phenol	Non tannin	Tannin phenol	Total phenol	Non tannin	Tannin phenol
0	858 ^a	328 ^a	530 ^a	560 ^a	302 ^a	260 ^a	356 ^a	200 ^a	156 ^a
36	511 ^b	187 ^b	324 ^b	420 ^b	243 ^b	174 ^b	328 ^a	199 ^a	129 ^a
48	409 ^c	170 ^b	239 ^c	354 ^b	219 ^{bc}	135 ^b	324 ^a	197 ^a	126 ^a
72	340 ^d	163 ^b	177 ^d	345 ^c	210 ^c	135 ^b	316 ^b	197 ^a	119 ^a

Content of phenolics decreased markedly in sorghum and moderately in cowpeas as a result of germination, while there was no significant decrease ($p>0.05$) in phenolic content decrease in green grams as result of germination. The tannin type phenols decrease more as compared to non-tannin phenols in all food grains. For sorghum, phenols decreased by 60 percent, tannins by 67 percent and non-tannin phenols by 50 percent after 72 hours germination. For cowpeas, the reductions were 38, 48 and 30 percent for phenols, tannins and non-tannin phenols respectively and 11, 24 and 2 percent, respectively in green grams. After 72 hours of germination, levels of phenolic compounds in sorghum (340 mg/g), which were high-tannin variety were more or less similar to those in cowpeas (345mg/g) and green-grams (316 mg/g). (Table 1)

The decrease of tannin compounds was rapid during the first 36 and 48 hours of germination and then at a slower rate up to 72 hours of germination for both sorghum and cowpeas.

Decrease in polyphenol content as result of germination has been reported by various workers (Breassani and Elias, 1980. Udayasakhara-Rao and Deosthale, 1987; Obozoba and Atii, 1991; Obizoba and Egbuna, 1992, Udayasakhara-Rao, 1995). Sharma and Sehgal (1992) observed a decrease in tannin content as a result of germination similar to the results obtained in this study, contrary to this, Khetarpaul and Chauhan (1990) did not observe any reduction in polyphenols in pearl millet as a result of germination. The observed decrease in content of phenolic compound as result of germination might be attributed to the leaching of phenolic compound during pre-germination soaking and to the tissue of filter paper surrounding the germinating seeds (which was moistened throughout the germination time) (Obizoba and Egbuna, 1992; Bakr, 1996). It is also likely that part of the phenolic compounds might have entered the endosperm with the imbibed water during pregermination soaking and germination processes and formed complexes with endosperm macromolecules like proteins and made them

not assayable by the method used. These phenomena have been reported by other researchers (Chavan et al., 1981; Salunkhe et al., 1990; Ayet et al, 1997, Chau and Cheung, 1997). The action of polyphenoloxidase (PPO) enzymatic activity may be another contributory factory to the decrease in phenolic compounds with germination. Udayasakhara-Rao and Deosthale (1987) observed an increase in PPO activity and decrease in tannin content, but with poor correlation with seed germination. They explained the poor correlation to be due to the different location of the PPO and tannins in the same seed. The nature or behaviour and structural configuration of phenolic compounds in food grains, enzyme specific and complexity of phenol interactions/reactions among others, might have contributed to the observed variation polyphenols reduction as a result of germination. This might account for the observed low reduction of polyphenol in green grams as compared to sorghum and cowpeas. It is however concluded that, germination process may be employed as an integral part of grain treatment by the community and therefore offer dual advantages of reduction of antinutritional factors like tannins and improve in nutrient bio-availability as well as nutritive value of food grains.

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The nutritive value of traditional processed and stored indigenous Vegetable Chipali in Dodoma region, Tanzania.

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Abstract

The nutritive value of Chipali (*Ipomea obscura*) an indigenous vegetable in Dodoma region and the effect of traditional processing on the nutrients contents were determined by AOAC methods. The results of this study indicated that crude protein, fat, fibre, ash, carbohydrate and moisture content of fresh Chipali were 3.60, 2.50, 2.11, 2.59, 3.42, and 85.78%, respectively. The mineral content of fresh Chipali were 336.0, 180, 165.0, 26, and 540.0 mg/100kg for K, Na, Mg, Fe, and Ca, respectively. The ascorbic acid content of the fresh vegetable was 11.35mg/100g. Traditional processing of Chipali resulted into loss of 19.72, 62.4, and 32.6% for crude protein, fat and ascorbic acid content respectively. However fibre and ash content were slightly affected by processing. Further loss of ascorbic acid of about 92.5% was observed after 6 weeks of storage. Processing of the vegetable reduced the mineral content by 4.46, 6.11, 5.45, 42.31 and 24.07%, for K, Na, Mg, Fe and Ca, respectively. Traditional processing and storage of processed Chipali resulted in significant ($P < 0.05$) decreased in all the nutrients. Based on the results of this study the use of traditional processed Chipali is likely to contribute to the poor nutrition of the rural population in Dodoma region unless otherwise supplemented with other locally available source of nutrients such as groundnuts and meat.

Key words: Ash, Ascorbic acid, Carbohydrates, Crude protein, Fat, Fibre, Mineral.

Introduction.

The importance of green leafy vegetables as a sources of nutrients in societies where consumption of animal based food products is low is well recognised (FAO, 1988). Green leafy vegetables and certain fruits are important sources of pro-vitamin A, carotenoids, ascorbic acid, riboflavin, minerals and other nutrients (Uiso and Manhunnah, 2000). Traditional, societies have been able to maintain adequate nutritional status through a wide variety of food staples together with wild leafy vegetables and fruits (Grivetti, 1978; Ogle & Grivetti, 1985). Some fruits, roots and leafy vegetables are consumed routinely, while many species are of importance only during times of seasonal shortages or drought (Grivetti et al., 1987). The use of a wide variety of vegetables, even though they

are low in amount of protein tend to complement each other in amino acids and leads to overall adequate protein intake (Ogle & Grivetti, 1985). Some of the indigenous food plants encountered in household gardens as weeds and wild plants are not only nutritious but are also strategic reserves of essential nutrients that are available at certain critical periods of the year when other more common sources of these nutrients are scarce or completely unavailable (Lockett et al., 2000 & Okigbo 1977). The indigenous vegetables in Tanzania includes mchicha (amaranth), majani ya kunde (cowpea leaves), majani ya maboga (pumpkin leaves), mnafu (nightshade), matembele (sweet potato leaves), mgagani (spider flower), kismvu (cassava leaves), ngogwe (African eggplant), mlenda (chochorne) and sukuma wiki (African kale) (FAO, 1973). These vegetable forms an essential component of the meal and contribute significantly to dietary requirements for nutrients such as Ca, Fe, Mg, Zn, ascorbic acid, riboflavin, thiamine, fibre and protein especially in areas of low animal protein availability and where cereals comprise most of the human diet (Lyimo et al., 1991; Maeda & Salunkhe, 1981). Green leafy vegetables are consumed on a daily basis, normally as a relish to accompany starchy foods such as maize, rice and sorghum (Anne, 1989). Apart from the contribution of valuable nutrients, vitamins and mineral vegetables are known to add variety of taste, colour and texture to diets (Rubartzk & Yamaguch, 1996).

In many areas of the world, edible vegetation is not utilised due to lack of information, some taboos, or personal preferences. Sometimes only when faced with starvation is when some population resort to consuming vegetative crops or plants, (Rubatzky & Yamaguchi, 1996). Chipali is one of the indigenous non-cultivated consumed by the native people of Dodoma region. It is a weed plant of the sweet potato family *Ipomea obscura*. It grows in rural areas in Dodoma and it is abundantly available during the rainy season and scarce in the dry season. To alleviate shortage of this during the dry season it is traditionally processed and stored in gourds for use during off season.

Considering the widespread nutrient deficiency problems and the important role green leafy vegetables play in human nutrition as reported in dietary surveys in Tanzania, this study was undertaken to assess the nutritive value and

the effect of traditional processing on the nutrient composition of Chipali.

Materials and Methods

Samples collection and preparation

Fresh and processed Chipali leaves was collected from Mvumi village, Dodoma region. The processed Chipali was collected in traditional storage containers (gourds) while fresh Chipali was collected in black coloured polythene bags to avoid exposure of the vegetable to light, which could lead to loss of some light sensitive vitamins. The processing of Chipali in the village involved picking the Chipali leaves, washing in water and cutting into small pieces and pounding them using pestle and mortar to form thick paste. The thick paste was made into pancake like forms and then sun dried. Once fully dried they were stored in special traditional containers (gourds) for future use.

Proximate composition, mineral and vitamin analyses.

Proximate composition of Chipali was determined using standard methods (AOAC, 1990). The moisture content was determined by drying using an air oven (WTC Binder, type E115 RWF 12/5) at 130°C for 1 h (method 14.004). Crude protein by the micro-Kjeldahl method using 6.25 as the conversion factor (method 14.063). Crude fat was determined by ether extraction using the Soxhlet extraction. The crude fibre by dilute acid and alkalis hydrolysis (method 7.054). Ash content of Chipali (*Ipomea obscura*) was determined by combusting 2g samples in a muffle furnace (Carbolate type RWF 12/5, Sheffield, England) at 550°C to constant weight (method 14.006). Ashes samples were transferred to a desiccator to cool and weight recorded. Carbohydrate was calculated by difference. Ascorbic acid (vitamin C) was determined by 2, 6-dichlorophenolindophenol visual titration method (AOAC, 1990). Potassium, magnesium and iron were determined by atomic absorption spectrophotometer while calcium and sodium by flame photometry method (AOAC, 1990).

Results and discussion

Table 1 presents the nutrient composition of fresh, processed and stored Chipali. A significant variation in the content of moisture, crude protein, fat, carbohydrates, and vitamin was observed between the fresh, processed and stored Chipali. The content of ascorbic acid (vitamin C) of the fresh Chipali leaves (11.36 mg/100g) was less than that of most leafy vegetables reported in other studies (Lyimo et al. 1991). Mosha et al., (1995) and Mosha et al., (1997) reported that the low value of Vitamin C could be due to unsuitable environmental conditions such as climate, soil and cultural practices. However, there was a significant ($P<0.05$) decrease of vitamin C after processing and during storage which could be attributed to oxidation of the vitamin. Processing and during storage which could be attributed to oxidation of the vitamin. Processing and sun-drying resulted in a significant ($P<0.05$) decrease in all the nutrients. The decrease was 19.72 and 62.40% for protein and fat content, respectively. The loss of crude protein during processing and storage of the vegetable can be explained by the fact that protein is easily denatured by heat (Salunkhe, 1974). There was a significant ($P<0.005$) variation in ascorbic acid during processing and storage. A loss of about 32.60% was experienced during processing and sun-drying. There was a further loss of about 92.80% at the end of six weeks storage.

The loss of Vitamin C content in the vegetable could be due to the fact that drying of the vegetable under sunlight without shade allows light to come in contact with the vegetable and enhance vitamin C destruction. Vitamin C may also be lost through leaching out as it is water soluble (Lyimo et al., 1991). Also uncontrolled temperature and oxygen availability accelerates the rate of vitamin C destruction by oxidation (Maeda, 1977)

Table 2 shows the mineral concentrations (mg/100g) for fresh, processed and stored Chipali. The iron content of

Table 1. The nutrient composition of fresh, processed and stored Chipali^{1,2}

Treatment	Moisture %	Protein %	Fat %	Fibre %	Ash %	Carbohydrate %	Vitamin C mg/100g
Fresh	85.78±0.36 ^a	3.60±0.49 ^a	2.50±0.02 ^a	2.11±0.40 ^a	2.59±0.02 ^a	3.42±0.74 ^a	11.35±0.21 ^a
Processed	10.80±0.18 ^b	2.89±0.34 ^b	0.94±0.06 ^b	2.01±0.01 ^b	2.56±0.02 ^b	82.06±0.34 ^b	7.65±0.00 ^b
Storage							
Weeks 2	10.70±0.18 ^b	2.87±0.85 ^b	0.70±0.11 ^c	2.00±0.01 ^b	2.55±0.04 ^b	82.37±0.73 ^b	6.03±0.12 ^c
Weeks 4	10.63±0.16 ^b	2.85±0.72 ^b	0.67±0.07 ^c	2.00±0.07 ^b	2.55±0.07 ^b	82.38±0.74 ^b	3.24±0.12 ^c
Weeks 6	7.05±0.19 ^c	2.84±0.42 ^b	0.48±0.08 ^c	1.98±0.29 ^b	2.55±0.06 ^b	86.23±0.48 ^b	0.54±0.11 ^c

¹ Means within a column with different superscripts are significantly different using Duncan's Multiple Range Test at $P<0.05$

² Mean# standard errors based on three observations.

fresh Chipali (*Ipomea obscura*) as per results of this study is 2.6mg/100g. This value is similar to that of other vegetables of the same family such as *Ipomea aquatica* (2.5mg/100g) as reported by Tindal (1983). There was no significant ($P>0.05$) variation of iron content during processing and storage for six weeks. However, significant ($P<0.05$) variation was observed in the rest of the minerals. The values for Ca, Na, Mg, and K were higher than the ones obtained in other studies for different vegetables (Lyimo et.al., 19912). Mosha et al.,

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Table 2 Mineral concentrations (mg/100g) in fresh, processed and stored Chipali^{1,2}

Treatment	Potassium	Sodium	Magnesium	Iron	Calcium
Fresh	336.0±0.85 ^a	18.0±0.17 ^a	165.0±0.37 ^a	2.6±0.02 ^a	540.0±0.38 ^c
Processed	321.0±0.49 ^b	16.9±0.18 ^b	156.0±0.19 ^b	1.5±0.01 ^b	410.0±0.34 ^d
Storage					
Weeks 2	260.0±0.42 ^c	17.3±0.11 ^b	113.0±0.45 ^c	1.3±0.06 ^b	330.0±0.16 ^c
Weeks 4	258.0±0.53 ^c	16.3±0.08 ^c	106.0±0.26 ^d	1.3±0.04 ^b	325.0±0.87 ^b
Weeks 6	255.0±0.79 ^d	15.4±0.09 ^d	98.0±0.45 ^e	1.2±0.05 ^b	322.0±0.24 ^a

¹ Means standard errors based on three observations

² Means within a column with different superscripts are significantly different using Duncan's Multiple Range Test at $P<0.05$

The variation in the mineral content during processing and storage could be due to leaching effect during washing of the vegetable. Processing decreased the mineral content of fresh Chipali by 4.46%, 6.11%, 5.45%, 42.31% and 24.0% for K, Na, Mg, Fe and Ca, respectively.

Based on these results fresh Chipali (*Ipomea obscura*) proved to be a rich source of minerals such Na, K, Mg, Ca, Fe, protein, fat, fibre and carbohydrates. However, the nutritive value of the vegetable decreased when traditionally processed and stored for an extended period of time in the traditional containers (gourds). To minimize the losses of vitamin C (ascorbic acid) and other nutrients of the vegetable during processing and storage it is important during sun drying the vegetable is not exposed directly to sunlight. Drying should be done under shade or the vegetable should also be stored in air tight containers to avoid the effect of oxidation. To restore the lost nutrients supplementation with locally available source of nutrients such as groundnuts and meat is recommended. Although improved solar drying technology already exists which is in many ways superior to the traditional drying technology its adoption in Dodoma region has lagged behind. Hence efforts to promote the solar drying technology in Dodoma Region needs to be intensified. This cheap drying technology should go hand in hand with improved storage structures that leads to more attractive, nutritious and hygienic dried vegetable products.

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Protein and Tannin Analysis of Sorghum Grain by Near Infrared Reflectance Spectroscopy

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Abstract

The objective of this study was to determine whether Near Infrared Reflectance Spectroscopy (NIRS) could be effectively used to predict the protein and tannin content in whole and dehulled sorghum grain. The range of protein content for the sorghum grain grown in 1983/84 and 1984/85 as determined by the Kjeldahl procedure was 7.4–16.7 and 8.4–15.1%, respectively. The protein content of sorghum grain was predicted with reasonable accuracy using NIRS. The standard error of prediction (SEPC) was 0.43 and 0.28% while the (*r*) between the Kjeldahl and NIRS was 0.99 (*p* < 0.01, *n* = 30) and 0.99 (*p*, *n* = 20) for the 1983/84 and 1984/85 crop years respectively. When the 1983/84 prediction equation was used to predict protein content in sorghum lines grown in 1984/85 the SEPC was 0.35% and (*r*) was 0.98 (*p* < 0.01, *n* = 20) and when the 1984/85 prediction equation was applied to the sorghum lines grown in 1983/84 the SEPC was 0.75% and the (*r*) was 0.99 (*p* < 0.01, *n* = 30). The tannin content of sorghum grains was determined by V-HC1/24h method as reference method. For the calibration and verification sets of sorghum grain samples, the tannin content ranged from 0–10%. The tannin content of the 1984/85 whole sorghum grain was poorly predicted with correlation coefficient (*r*) 0.86 (*p* < 0.01, *n* = 20). Likewise, the tannin content of the ground sorghum grain of the same set of samples was poorly predicted by NIRS with correlation coefficient (*r*) 0.86 (*p* < 0.01, *n* = 20). The high values of SEPC 3.54 and 1.44% and the low ratios of range to SEPC 2.82 and 6.72 for the whole and ground sorghum grain, respectively, demonstrate the NIRS cannot be used to predict tannin in sorghum, particularly where precision is required. It can however, be used in screening programs to group sorghum into categories of tannin content. Tannin content of two progressively dehulled sorghum lines was predicted with reasonable accuracy using NIRS. The SEPC was 0.11% and (*r*) was 0.99 (*p* < 0.001, *n* = 20) for sorghum line IS9487 and SEPC of 0.35% and (*r*) 0.95 (*p* < 0.01, *n* = 30) for sorghum line IS 9613.

Key words: sorghum, dehulling, near infrared reflectance spectroscopy, protein tannin

Introduction

Near Infrared Reflectance Spectroscopy (NIRS) is a relatively recent addition to the analytical tools available to the grain processor and food technologist. It measures absorption by molecular bonds, and most NIRS applications are based on correlations between these absorption and chemical constituents (Velasco et al, 1998). This technique minimizes the need for wet chemistry and also offers the advantage of greater speed analysis (Osborne and Fearn 1986). As a consequence, the technique is used where rapid and reliable screening of large numbers of samples is necessary, for example, in trading, plant breeding and quality evaluation of wheat (Stephen et al., 1996; Stephen et al., 1995; Stephen and Norries, 1993; Davies and Wright, 1984; Hirschfeld and Stark, 1984). It has been widely used for analysis of major rather than trace constituents in foods although there are few exceptions (Ben-Hdech et al., 1998). In addition, it has become an approved method for the determination of protein and moisture of wheat (Anon 1980, Williams and Cordeiro, 1985). NIRS analysis is now the official method to determine protein in wheat for trading purposes in both the United States and Canada (Williams, 1975).

The objective of this research was to study the potential of NIRS to estimate the protein and tannin contents in whole and dehulled sorghum grain

Materials and Methods

Materials

Sorghum breeding lines were obtained from ICRISAT, India. All lines were brown seeded, high tannin type and were grown during the 1983/84 and 1984/85 post-rainy seasons in the red soils with row spacing of 0.75m and row length of 4. M. There were 35 to 40 plants per row giving a plant population density of 18 to 20 plants/m² after thinning. The mature crop was harvested, sun dried and hand threshed to avoid the excessive kernel breakage by a mechanical thresher. The moisture content (AACC, 1983; Method 44:15A) of samples was 8.1 ± 0.5% (standard deviation). The cleaned grains were stored in double

plastic bags at 15°C. All analyses of the samples were complete within eight months of harvest.

Analytical Methods

Protein Content

Grain was ground in a Udy Cyclo-Tec mill to pass through 0.5 mm screen and protein determined by the automated Kjeldahl procedure (AOAC, 1984; Method 7.021).

Tannin Content

Tannin content was determined using the Vanillin Hydrochloride (V-HCI) and Modified Vanillin Hydrochloride (MV-HCI) methods of Burns (1971) using reagent blanks described by Price et al. (1978). Dehulling was achieved by using the Tangential Abrasive Dehulling Device (TADD, venables Machine Works Ltd, 502-50th Street E, Saskatoon, Saskatchewan) equipped with a 12-cup sample plate and a grinding wheel (Norton Canada Inc., P.O. Box 3008, Hamilton, Ont) with the following specifications: A36L5VBE, 10" diameter, 3/8" thick, 1" arbour, V-sided, 90RD, diameter + 0.005" (Reichert et al., 1986). The TADD was operated at 1450 r.p.m. In order to generate many samples varying in tannin content, samples of 20 g were weighed into the eight-sample cup of the TADD. The hinged lid was closed and the gains dehulled to different levels, starting with zero time followed by five second intervals. The dehulled grains was removed from the sample cups using the vacuum-aspirating device described by Oomah et al. (1981). At each level of dehulling, the tannin content was determined using the V-HCI/24h.

NIRS

All samples were scanned by NIRS on a Technicon 500 Infra-Alyzer (Technicon, Tarrytown, NY) equipped with a Hewlett-Packard Micro 26 computer (Hewlett-Packard Company, Data Systems Division, 11000 Wolfe Road, Cupertino, CA 95014) and Technicon Software version 5, was used to record the reflectance spectra of both whole and ground sorghum grain as log1/R from 1100-2500nm. The computer averaged data from spectral curves for each sample before recording the data. Statistical analyses were made with the software furnished with the Technicon instrument. The samples were scanned from 100 – 2500 nm at 4nm intervals. The Technicon best-fit combination of three wavelengths search program selecting from all possible combinations was used to choose the appropriate wavelengths.

Results and Discussion

To calibrate the near infrared instrument for protein analysis, several wavelength combinations were

generated by the stepwise multiple regression using the calibration set of sample (Table 1).

Table 1: Calibration equation, multiple correlation coefficient and standard error of calibration for using NIRS to predict sorghum protein content determined by the Kjeldahl.

	Year of Growth			
	1983/84		1984/85	
Samples Number	30		30	
Range (%)	7.41-16.7		8.44-15.1	
Mean (%)	10.9		11.1	
Calibration Equation ^a	λ (nm)	constant	λ (nm)	constant
a		8.9910		23.608
b ₁	1650	-1516.1	2150	-1424.6
b ₂	1690	2779.7	2170	1991.6
b ₃	1740	-1443.3	2230	-580.14
Calibration Statistics				
R ^b		0.99**		0.98**
SEC ^c		0.37		0.24

^aEquation format: % Protein = a + b₁l₁ + b₂l₂ + b₃l₃ where a = intercept constant from regression, b_n = constant from regression for each wavelength, l_n = log1/R (relative reflectance of sample compared to standard deviation for each wavelength).

^bMultiple correlation coefficient for calibration of NIR instrument.

^cStandard error of calibration.

**Significant at 1% level of significance.s

The best-fit equation selected to predict protein content for the 1983/84 crop was:

$$\% \text{ Protein} = 8.9910 - 1516.1 (A_{1650}) + 2779 (A_{1690}) - 124.3 (A_{1740})$$

Where A = log 1/reflectance at respective wavelength

For the 1984/85-sorghum crop, the best-fit equation selected for predicting protein content was:

$$\% \text{ Protein} = 23.608 - 1424 (A_{2150}) - 1991.6 (A_{2170}) - 580.14 (A_{2230})$$

The wavelengths selected to predict protein for both years were in conformity with Mark and Workman (1986) that wavelength searches performed on different data sets result in different wavelengths being selected. This observations is caused by intercorrelations that exist

between absorbance values at different wavelengths, which cause the noise characteristics of the data to become the factor determining the actual set that is chosen. Performing wavelength searches increases the probability of a wavelength set being selected that gives anomalously good results by chance alone, because the noise is being fitted, rather than the absorption characteristics of the sample.

The performance of the best-fit equation for predicting protein content was checked by NIRS using the verification set of samples. The NIRS predicted protein content was significantly correlated ($r = 0.99$, $p < 0.01$, $n = 30$ and $r = 0.99$, $p < 0.01$, $n = 20$) with wet chemistry protein values for the 1983/84 and 1984/85 sorghum grain, respectively (Table 2).

Table 2: Performance of NIRS method used to predict protein content of verification set of sorghum samples

year	n	Kjeldahl method			NIRS		
		Range %	Mean %	SD ^a %	Mean %	SEPC ^b %	r ^c Range/SEPC ^d
1983/84	30	7.63-16.1	10.9	0.21	11.0	0.43	0.99 20.8
1984/85	20	8.99-13.0	11.5	0.07	11.3	0.28	0.99 16.5

^aStandard deviation for duplicate analysis ($SD = \sqrt{\sum d^2/2n}$), where n = number of duplicate analysis and d = difference between duplicate analysis.

^bStandard error of prediction which was corrected for machine bias.

^cCorrelation coefficient between protein content analysed by the Kjeldahl and the NIRS methods.

^dRange of the chemical values divided by SEPC.

The ratios of the range to SEPC for the verification subsets were 20.8 and 16.6 for the 1983/84 and 1984 crop years, respectively. These ratios were considered higher than the ratio of 10, which according to the instrument manufacturer is considered acceptable for NIRS applications, where accurate predictions are required (Williams and Sobering, 1993; Anon, 1980). Based on the high values of r (0.99), low values of SEPC (.43 and 0.28%) and high ratio for the range to SEPC (20.8 and 16.5) for the 1983/84 and 1984/85 crops, respectively, it is possible to accurately use NIRS technique to predict protein in ground sorghum grains. The correlation between wet chemistry values for protein and NIRS predicted protein was highly significant ($r = 0.98$, $p < 0.01$, $n = 20$) when the calibration equation for the 1983/84 was used to predict protein in the 1984/85 sorghum. The same was also true for the vice versa with ($r = 0.95$, $p < 0.01$, $n = 30$).

In an attempt to predict tannin content in the whole sorghum grain using NIRS the tannin content was first

determined by V-HCI/24h method as reference method. The tannin content of whole sorghum samples used for the calibration and verification sets was relatively evenly distributed from 0 to 10%. The ratio of the range to standard deviation (SD) for calibration set was 142, a value higher than the ratio of 20 therefore calibration of the instrument was possible.

To calibrate the NIRS instrument for tannin analyses of whole grain, several wavelength combinations were generated by the stepwise multiple regression using the calibration set of sample (Table 3). The best-fit equation selected to predict tannin content of whole sorghum grain was:

$$\% \text{ Tannin} = 17.70 + 1099.0 (A_{1824}) + 826.04 (A_{1668}) + 2472.9 (A_{1872}) - 4395.8 (A_{1824})$$

Table3: Calibration equation, multiple correlation coefficient and standard error of calibration for using NIRS to predict tannin content in whole sorghum grain as determined by the V-HCI/24h method.

	Year of Growth	
	1984/85	
Samples		
Number	30	
Range (%)	0-10	
Mean (%)	4.22	
Calibration Equation ^a	λ (nm)	constant
a	-	17.70
b ₁	1824	1099.0
b ₂	1668	826.04
b ₃	1872	2472.9
b ₄	1824	-4395.8
Calibration Statistics		
R ^b	0.90**	
SEC ^c	0.27	

^aEquation format: $\% \text{ Tannin} = a + b_1 1_1 + b_2 1_2 + b_n 1_n$

where a = intercept constant from regression, b_n = constant from regression for each wavelength, $1_n = \log 1/R$ (relative reflectance of sample compared to standard deviation for each wavelength).

^bMultiple correlation coefficient for calibration of NIR instrument.

^cStandard error of calibration.

**Significant at 1% level of significance.

Table 4: Performance of NIRS method used to predict tannin content of verification set of whole sorghum grain samples.

V-HC1/24h method					NIRS			
year	n	Range %	Mean %	SD ^a %	Mean %	SEPC ^b %	r ^c	Range/SEPC ^d
1984/85	20	0.10-10.1	4.24	0.14	4.23	3.54	0.66	2.82

^aStandard deviation for duplicate analysis ($SD = \sqrt{\sum d^2/2n}$), where n = number of duplicate analysis and d = difference between duplicate analysis.

^bStandard error of prediction which was corrected for machine bias.

^cCorrelation coefficient between protein content analysed by the V-HC1/24h and the NIRS methods.

^dRange of the chemical values divided by SEPC

The tannin content of the verification set of samples was determined by NIRS to check the performance of the best-fit equation (Table 4). The NIRS predicted tannin content was significantly correlated ($r = 0.66$, $p < 0.01$, $n = 20$). The low value of the correlation coefficient, the high SEPC value (3.54), and the low ratio (2.82) of range to SEPC suggest that the NIRS technique is of little or no value for analysis of tannin content of whole sorghum grain because of non uniform nature of the sorghum grains. The uniformity can be improved by grinding to uniform particle size. To calibrate the near infrared instrument for tannin analyses of ground grain, several wavelength combinations were generated by stepwise multiple regression using calibration set of samples (Table 5).

Table 5: Calibration equation, multiple correlation coefficient and standard error of calibration for using NIRS to predict tannin content in ground sorghum grain as determined by the V-HC1/24h method.

Year of Growth		
1984/85		
Samples		
Number		30
Range (%)		0-10
Mean (%)		4.17
Calibration Equation ^a	λ (nm)	constant
a	-	17.640
b ₁	2050	2471.9
b ₂	2070	-4561.9
b ₃	2120	2115.5
Calibration Statistics		
R ^b		0.92**
SEC ^c		1.80

^aEquation format: % Tannin = $a + b_1 1_1 + b_2 1_2 + b_n 1_n$ where a = intercept constant from regression, b_n constant from regression for each wavelength, $1_n = \log 1/R$ (relative reflectance of sample compared to standard deviation for each wavelength).

^bMultiple correlation coefficient for calibration of NIR instrument.

^cStandard error for calibration.

**Significant at 1% level of significance.

Table 6: Performance of NIRS method used to predict tannin content of verification set of sorghum samples.

V-HC1/24h method					NIRS			
year	n	Range %	Mean %	SD ^a %	Mean %	SEPC ^b %	r ^c	Range/SEPC ^d
1984/85	20	0.10-9.77	4.20	0.06	4.19	1.44	0.86	6.72

^aStandard deviation for duplicate analysis ($SD = \sqrt{\sum d^2/2n}$), where n = number of duplicate analysis and d = difference between duplicate analysis.

^bStandard error of prediction which was corrected for machine bias.

^cCorrelation coefficient between protein content analysed by the V-HC1/24h and the NIRS methods.

^dRange of the chemical values divided by SEPC

The best-fit equation selected to predict tannin content was:

$$\% \text{ Tannin} = 17.640 + 2471(A2050) - 4561.9(A2050) + 2115.5(A2120)$$

The NIRS predicted tannin content was significantly correlated ($r = 0.86$, $p < 0.01$, $n = 20$) (Table 6). The low values of the correlation coefficient, the high values of SEPC (1.44) and the ratio of range to SEPC (6.72) demonstrate that the NIRS technique is of limited value for analysis of tannin content of ground sorghum grain. It is not useful for measurements of tannin where precision is required. However, it can be used in screening program to group sorghum into few categories (low, medium and high tannin content).

To calibrate the near infrared instrument for tannin analyses of progressively dehulled and ground grain, several wavelength combination were generated by stepwise multiple regression using the calibration sets of samples (Table 7). The best-fit equation selected to predict tannin content of progressively dehulled sorghum line IS9487 was:

$$\% \text{ Tannin} = 4.5020 + 471(\text{A1680}) - 1280.4(\text{A1700}) + 811.08(\text{A1730})$$

For the sorghum line IS9613 the equation was:

$$\% \text{ Tannin} = -16.992 + 1654(\text{A1730}) - 1599.2(\text{A1800})$$

The NIRS predicted tannin content was significantly correlated with V-HCI/24h tannin content for line IS9487 and IS9613 ($r = 0.99$, $p < 0.01$, $n = 20$ and $r = 0.95$, $p < 0.01$, $n = 30$), respectively. The ratio of the range of SEPc for the verification set for line IS9487 was 19.1 while the value for line IS9613 was 11.3. The high values of the correlation coefficients, low SEPc values (0.11 and 0.35%), and high ratio of range to SEPc for lines IS9487 and IS9613, respectively, indicate that it is possible to accurately use the NIRS technique for accurate analysis of tannin content in ground dehulled sorghum grain.

Table 7: Calibration equation, multiple correlation coefficient and standard error of calibration for using NIRS to predict tannin content in dehulled samples from two sorghum lines.

	Sorghum Line			
	IS9487		IS9613	
Samples				
Number	30		27	
Range (%)	0.54-2.58		1.07-5.14	
Mean (%)	1.33		2.55	
Calibration	λ	constant	λ	constant
Equation ^a	(nm)		(nm)	
a	-	4.5020	-	16.992
b ₁	1680	471.24	1730	-1654.0
b ₂	1700	-1280.4	1800	1599.2
b ₃	1730	811.08		
Calibration				
Statistics				
R ^b	0.99**		0.98**	
SEC ^c	0.07		0.25	

^aEquation format: $\% \text{ Tannin} = a + b_1 I_1 + b_2 I_2 - b_3 I_3$ where a = constant from regression for each wavelength, $I = \log 1/R$ (relative reflectance of sample compared to standard deviation) for each wavelength.

^bMultiple correlation coefficient for calibration of NIR instrument.

^cStandard error of calibration

**Significant at 1% level of significance.

Table 8: Performance of NIRS methods to predict tannin content (V-HCI/24h method) of verification set of dehulled samples from two sorghum lines.

Sorghum Line	n	V-HCI/24h method				NIRS		
		Range %	Mean %	SD ^a %	Mean %	SEPc ^b %	r ^c %	Range/SEPc ^d
IS9487	20	2.10 (0.48-2.58)	1.31	0.06	1.34	0.11	0.99	19.1
IS9613	30	3.96 (1.09-5.05)	2.52	0.17	2.51	0.35	0.9	11.3

^aStandard deviation for duplicate analysis ($SD = (\sum d^2/2n)^{1/2}$), where n = number of duplicate analysis and d = difference between duplicate analysis.

^bStandard error of prediction which was corrected for machine bias.

^cCorrelation coefficient between protein content analysed by the V-HI/24h and the NIRS methods.

^dRange of the chemical values divided by SEPc

Conclusion

NIRS can successfully be used to predict protein content in ground sorghum grain and tannin content in ground and dehulled sorghum grain. The technique however, cannot be used to predict tannin content in whole sorghum grain, but can be used for screening and grouping sorghum into groups of low, medium and high tannin contents.

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The effect of birth intervals on child nutritional status in Tanzania

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Abstract

Many studies on Mortality show that short birth intervals have a strong relationship to the survival of children under five years of age. However, very few studies have been conducted to demonstrate the relationship between birth intervals and nutritional status of children under five years of age. This paper investigates the effect of birth intervals on child nutritional status in Tanzania using data from the 1992 Tanzania Demographic and Health Survey (TDHS). Descriptive results show that more than 15 percent of children were born with a preceding birth interval of 24 months or less. Rural areas are observed to have a higher proportion of such children than urban areas. A binary logistic regression analysis is used in this paper to assess the relative effect of the birth interval on child nutritional status and its results show that short birth intervals are persistently associated with poor nutritional status even after controlling for demographic and socio-economic variables. The chances of being malnourished for children with a preceding birth interval of 24 months or more is 19 percent less than for children with a preceding birth interval of less than 24 months. Findings on subsequent birth interval contrast with what was expected. Increasing subsequent birth interval is observed to be associated with the deterioration of child nutritional status. Other demographic and socio-economic variables which observed to have significant association with child nutritional status are; area of residence, child sex and age, maternal age, education, economic status, contraceptive use, prematurity, parity and birth weight.

Key Words: Children under five, Child nutritional status.

Introduction

The importance of birth spacing for mother and child health is now established as a corner stone for both policy-makers and demographers in the field of family planning (1). If births are spaced correctly, mothers will get adequate time to recover from previous pregnancies and hence the next child will be born with a normal birth weight and there will be more time for breast feeding and child care. Furthermore, there is a reduced risk of unwanted pregnancies when spacing is emphasized. The ultimate benefit of these advantages is better nutritional status for children.

The relationship between birth interval and child mortality has been shown to be a remarkably consistent and strong association in many studies. (De Sweemer - 1984). In this study the influence of child spacing on child survival" observed that infant mortality decreased as the length of the preceding birth interval increased (2). Using the national data from the British Perinatal Survey, Fredrick and Aldelstein (1973) investigated the influence of spacing on the outcome of pregnancies and found that there was a significantly higher rate of neonatal death. When inter-pregnancy intervals were less than six months(3).

Cleland and Zeba in their study on "The Effect of Birth Spacing on Childhood Mortality in Pakistan" observed that, at all ages, mortality risk decreased with longer birth intervals and that this effect was more pronounced for post-neonatal mortality. However, they also found that among infants with birth intervals longer than three years, further increases in birth interval were not associated with more significant decreases in neonatal mortality(4)

The few studies which have concentrated on determining the relationship between birth interval and nutritional status of children under five years of age have often shown that the probability of being malnourished for a child born less than 24 months after the preceding child was significantly higher than for a child whose preceding birth interval was 24 months and above(5). This has been shown particularly in various states in India, but also in some other sub-Saharan African countries(6,7,8). The analytical conceptual framework applied in this study is based on the hypothetical mechanism developed by Pebley and Alo(9). However, some modifications were made to fit our hypothetical causal relationship between birth interval and child nutritional status.

Possible pathway of influence.

The length of the previous birth interval may affect the nutritional status of a child in the following ways;

- i) A child born after a short birth interval will usually have an older sibling who is very close in age, unless the older sibling dies before the first child's birth. The existence of an older sibling of similar age may mean that the child has more competition for the scarce resources that both children need to survive and remain healthy. This

possible path of influence is usually referred to as the 'sibling rivalry' hypothesis.

- i) A short birth interval may prevent the mother from recovering adequately from one pregnancy before beginning another. This may result in a higher risk of malnutrition to the second child because pregnancy and breast feeding deplete maternal nutritional resources making it likely that a woman will give birth to a baby with low birth weight(10). This hypothesis is known as the 'maternal depletion' theory.
- ii) Short inter-birth intervals may also allow inadequate time for a woman to regain muscle tone in reproductive tissues after a pregnancy and may lead to an increased incidence of cervical incompetence towards the end of the next pregnancy resulting in an increase. Incidence of pre-term births(11).

The length of the birth interval between two births may affect nutrition status of the older child in the following ways;

- i) When a woman becomes pregnant she is likely to terminate breast-feeding or at least begin to wean the older child. As a consequence, a short subsequent interval may adversely affect the nutritional status of the older child through early termination of breast feeding.
- ii) The death of a young child is likely to affect the subsequent birth interval by shortening the duration of breast-feeding and the associated length of postpartum ovulation. In many societies, the death of a child may also cause parents to attempt to have another child more quickly in order to replace the child who died. Given this situation, it is expected that if the previous child died then the interval prior to the next child's birth will be shorter than if the previous child had survived. The effect of this on the nutritional status of the surviving child is likely to be governed by maternal depletion or sibling rivalry as described above. There is an additional risk of poor nutritional status associated with the clustering of poor mortality and nutritional outcomes within. Families(12).

Objective of the Study

The main objective of this study was to use anthropometric survey data to find the factors that are associated with poor childhood nutritional status in Tanzania. The results of such a study can be used to determine which group are more susceptible to under-nutrition, as well as suggesting reasons why poor nutrition

of children is occurring. In particular, the strength of the association between birth interval and nutrition after controlling for other socio-economic and demographic factors is investigated.

Methodology

Data used in this analysis was from the Tanzania Demographic and Health Survey (TDHS) conducted in 1992. The survey provides information on children under five years of age and their mother's characteristics. Information on children under five years of age include; date of birth, sex, birth weight, current survival status, age, age at death, feeding practices and weight and length. Information for mothers include; age, education, marital status and knowledge of contraceptive use, weight and height. In total, a nationally representative sample of 5530 children was available for this analysis.

Height-for-age, weight-for-height and weight -for-age are used as indicators for a child nutritional status. These indices are expressed in standard deviations from a reference population (SD) or Z-scores using the NCHS/CDC/WHO recommended reference. The terms stunting, wasting and underweight are used to describe children falling more than two standard deviation below the reference median in height-for-age, weight-for-height and weight-for-age, respectively(13).

There are some restrictions applied on this analysis to ensure that the estimation of effects is appropriate. Multiple births are identified separately in the analysis due to the problem on defining the preceding and subsequent birth interval. Further, multiple births have a unique characteristics of low birth weight which may result in overestimation of nutritional problem. Women are classified as pregnant, non pregnant, lactating and non lactating to avoid overestimation or underestimation of maternal nutrition.

Response Variables.

Child nutritional status was the response variable for this analysis. For multivariate analysis of the differential in anthropometric status, height-for-age index was chosen as the most appropriate response variable because of its long term reflection on child nutritional status. Two categories were formulated for the children in the survey. These were; malnourished (Height-for-Age Z-score; more than two standard deviations below the reference median) and not malnourished (Height-for-Age Z-score; less than two standard deviations below the reference median).

Explanatory Variables

The main explanatory variable included in the analysis was the length of birth interval in completed months.

Since both preceding and subsequent birth intervals have a possible effect on child nutritional status, both were entered into the model. Given the empirical evidence that more than half of the births in Tanzania occur after an interval of 24 months (14,15), both categories were grouped into two; birth interval less than 24 months and those with 24 months and above.

In order to find the association between birth intervals and nutritional status, independent variable like area of residence, maternal age, maternal education, child age and sex, economic status, survival of the preceding child, breast feeding duration, parity, pre-maturity, marital status, maternal nutritional status and contraceptive use were controlled. Each of these independent variables is described below.

The place of residence is classified into rural and urban areas by adopting the definition used by the Tanzania government and more specifically by population census and TDHS reports (16). Maternal education is defined as the level of education a woman has attained and is categorised as; no education and low primary education; upper primary education and secondary and higher education. In order to establish categories of economic status, radio ownership is used as a proxy for household economic status. Radio is the most evenly distributed owned property across all societies in Tanzania and is a very strong economic indicator(17). Those women residing in households owning a radio are classified as economically better than those not owning a radio.

The sex of the child was included in order to determine whether any difference in nutritional status existed between the sexes even after controlling other variables. Included also were the age of child and the survival status of the preceding child which are also potential confounding factors for the relationship between birth interval and nutritional status of a child. If the proceeding child died before it was weaned, the death tend to terminate breast-feeding and hence the mother will resume ovulation and conceive again sooner than she would have done if the child survived.

A short duration of breast-feeding may place a child at great risk of death or illness because of the beneficial effects of the breast-feeding and at the same time the length of the subsequent interval may be reduced due to the ovulatory effects. If the index child dies while still breast feeding, the subsequent interval is likely to be shorter because of the cessation of breast-feeding. In the analysis, duration of breast-feeding was categorised into three groups; below 18 months, 18-23 months and 24 months or more. Children still breast-feeding were identified and put into a separate category.

Maternal age and parity are additional confounding variable, which are taken into consideration in this analysis. The interval between births is closely linked to the age of the mother at child birth and to the number of children she has previously delivered. Fecundability typically declines with increasing maternal age and therefore older mothers tend to experience longer intervals than younger mothers (17). In this analysis maternal age was categorised as; below 20, 20-24, 25-29, 30-34, or 35 years and above. For the case of parity, literature shows that high parity tends to be associated with practice of short birth intervals. If the birth occurs prematurely the interval is obviously shorter than (18) the birth had been carried to full term (17). Since our definition of birth intervals is based on birth to birth time space rather than the duration between women's conceptions, gestational age is likely to be an important potential confounding factor when birth intervals are used to measure birth spacing, short birth intervals in all societies contain an over-representation of premature births, which have an increased risk of mortality throughout their first year of life. The use of conception interval rather than birth interval eliminates this problem as long as they are calculated from data on gestational age and by subtracting nine months from birth interval. In addition by categorising birth interval into duration of less than 24 months versus 24 months and above means that the bias which might result from gestational age variation is reduced. However, TDHS does not include data on gestational age, therefore, the available information of child pre-maturity (a dichotomous item comprising 'premature' or 'born on time') is used to eliminate the confounding effects of gestational age. Under the hypothesis of sibling rivalry, the presence of several young children in a household creates a situation of competition, which pits the children against one another in their efforts to win the mother's attention and to gain access to care and nourishment (18). Children born last who in theory are less armed in this vital combat than their elder siblings, are in a risk of being more often malnourished, more often sick and therefore run a higher risk of dying. However, in this analysis, birth interval is regarded less as a direct cause of the poor nutritional status of a child than as factor which, together with others, give rise to the conditions necessary for it. Since the determining factor is the number of very young children present in the household, a short birth interval cannot cause competition between children unless the preceding child is still alive at the time of the younger one's birth and is still living in the parent's home. The variable for the presence of young children in a household is constructed by counting the number of under five years children that a woman has, at time of the interview. For each particular child, presence or absence of older children is used as a categorical variable.

Marital status represent exposure to sexual intercourse

when considered as an associated factor with birth interval and fertility in general. On explaining historical patterns of cross-sectional variation in fertility, the proportion of the population ever married, the age at marriage or entry into sexual union and the prevalence of widowhood, divorce and remarriage are sometimes more powerful factors than fertility within marriage itself. In addition, the existence of a husband might have an influence on the resources available to a household and therefore may affect the quality of food and health services available to a child. In this study marital status was grouped into three categories. These were; married polygamously, married monogamously and a last category combining never married, widowed, divorced and separated.

Repeated cycles of pregnancy and lactation are among the factors leading to a state of chronic under nutrition among women. Loss of weight due to the calorie, vitamin, protein and mineral requirements for pregnancy and lactation may lead to poor nutritional status not only to women themselves but also to their children (18). In this study, women's nutritional status is controlled for. Women with Body Mass Index (BMI) less than 18.5 are classified as malnourished.

Statistical Analysis

The overall nutritional status of children aged 1-59 months old was calculated for three anthropometric indices, height-for-age, weight-for-height and weight-for-age. The prevalence of undernutrition using any of these three indicators is the percent of children who fall below the cut-off point of minus two standard deviation Z-scores. These scores were calculated by applying the software package ANTHRO (19). Differential of child undernutrition according to demographic and socio-economic characteristics were analysed using the statistical package SPSS/PC+

The height-for-age Z-scores were used as the outcome variable to assess the effect of birth intervals on nutritional status while controlling for the effect of other demographic and socio-economic variable. A binary logistic regression model was applied to the data on children under five years of age using a statistical package known as Generalised Linear Interactive Modelling (GLIM). All explanatory variables were entered as covariates in the model. In this model, the response variable depends on the value assumed by the

explanatory variables and the difference between the explanatory and response variable is temporal in character with the explanatory variables preceding the response variable in time (20). The event of a child being malnourished or not is assumed to be independent from one to another. Since the purpose of this analysis was to study the effect of each factor, all the variables under study were entered into the model by forward stepwise selection technique. The Wald test was used to test whether each effect was significant ($p < 0.05$).

Results

Descriptive results

The results presented in Table 1 shows the prevalence of birth intervals among children under five years of age from the survey. More than two third were born with preceding birth intervals of 24 months and above, and one quarter were had subsequent birth interval of the same duration. There was only a slight difference in the prevalence of long birth intervals over zones, with the exception of West Lake Zone (76.9 percent), which was observed to have the highest prevalence. In contrast, Zanzibar had the highest prevalence of short birth intervals among children for both preceding and subsequent interval. Children in rural areas were born at shorter birth intervals as compared to their counterpart in the urban areas.

Table 1 percent distribution of children aged 1-59 months by birth interval and location

Table 2 shows descriptive results of nutritional status

Selected Background Characteristics	Birth Interval (Months)						No. of Children
	Preceding Interval			Subsequent Interval			
	<24	=>24	First Birth	<24	=>24	Last Birth	
Zone							
Central	14.9	69.3	15.8	6.9	28.2	64.9	1195
Northern	19.9	62.7	17.8	11.2	22.2	66.7	483
Coast	11.9	68.4	19.7	5.5	22.7	71.8	599
Southern	10.9	71.9	17.2	4.2	21.7	74.1	826
Southern Highlands & Western	13.8	68.1	18.1	6.0	26.2	67.7	1113
West Lake	19.3	64.9	15.8	8.9	26.5	64.6	992
Zanzibar	21.1	60.9	18.0	12.1	19.9	68.0	322
Area of Residence							
Urban	14.3	64.9	20.9	6.3	22.0	71.9	823
Rural	15.0	68.0	16.5	7.4	25.0	67.2	4702
All	15.3	67.5	17.2	7.2	24.9	67.9	5530

among children under five years of age by demographic and socio-economic background characteristics. The prevalence of stunting, wasting and underweight stood at 44.2, 6.4 and 29.4 percent respectively. With the exception of wasting, other indicators showed slightly higher proportions of vulnerability among children born at

preceding intervals less than 24 months.

There were appreciable differences in nutritional status across child sex, birth order, sex of the preceding child and parity. About 29 percent of Tanzania children under five years of age are underweight for their age, which may reflect stunting, wasting or both. Stunting, wasting and underweight are less common among children aged less than six months. However, they become increasingly common during the first year of life. Results on children's nutritional status by zone shows some interesting differences as follows: Wasting and underweight were less common in Southern Highlands and West Zone, West Lake, Central and Northern Zones. Zanzibar and Southern Zone had a higher proportion of children underweight than other areas. Rural areas in all zones were found to have rates of malnutrition (underweight, stunting and wasting) as compared to urban areas. A similar pattern is observed for maternal education. More than half of the children whose mothers are not educated and those who have lower education are stunted.

Multivariate results

Multivariate findings presented in Table 3 show that birth intervals have a persistent effect on child nutritional status even after controlling for other demographic and socio-economic variables. Children who have preceding birth intervals of 24 months or more have their chances of being malnourished decreased by 19 percent compared with those with shorter preceding birth intervals. However, contrasting results are observed for the effect of subsequent birth interval on nutritional status whereby as a child's succeeding birth interval increases from less than two year to 24 months and above, the chance of being malnourished increases by 76 percent.

Considering the magnitude of the odds ratios for individual variables, the child's age is observed to have the strongest effect, followed by multiple births, zone, subsequent birth interval, prematurity and area of residence. Also, significant ($p < 0.05$) are maternal education, subsequent birth interval and child's sex. Clearly, there is a marked effect on nutritional status as the child's age increases. The odds of a child being

Table 2 Percent distribution of children (1-59 months) classified as stunted, wasted and underweight by selected characteristics.

Chacteristics	Stunted1	Wasted2	Underweight3	No. of Children
Preceeding birth interval				
First born	44.3	6.7	26.8	949
Less than 24 months	49.2	5.9	33.8	948
24 months and above	43.1	6.4	29.0	3733
Subsequent birth interval				
Last born	41.1	7.1	30.0	3754
Less than 24 months	41.2	4.8	25.1	394
24 months and above	53.6	4.8	28.8	1378
Child's sex				
Male	46.0	6.9	30.4	2754
Female	42.5	5.9	28.4	2776
Child's age (Months)				
Less than 6	12.3	3.3	4.9	569
6-11	28.1	6.3	27.9	619
12-23	50.0	10.9	37.8	1258
24-35	48.6	5.6	34.3	1117
36-47	53.0	4.8	28.2	1009
48-59	51.8	5.0	29.2	958
Birth order				
First	44.3	6.7	26.8	949
2-3	42.9	5.9	27.7	1787
4-5	44.4	6.7	32.4	1233
6+	45.7	6.4	30.4	1561
Children under five (number)				
1	44.5	7.7	30.4	1342
2	45.6	6.0	30.2	2892
More than 2	41.0	5.8	26.5	1296
Children ever born (number)				
Less tha 3	42.4	6.7	27.8	1556
3-6	44.5	6.1	29.5	2728
6+	45.9	6.5	31.1	1246

Continued

Characteristics	Stunted ¹	Wasted ²	Underweight ³	No. of Children
Survival Status of preceeding child				
Alive	44.1	6.4	29.9	3939
Dead	45.3	5.6	29.9	642
First born	44.3	6.7	26.8	949
Sex of preceeding child				
Male	44.5	5.9	29.4	2288
Female	44.0	6.7	30.4	2293
First born	44.3	6.7	26.8	949
Maternal nutrition Status				
Malnourished	52.2	12.0	46.6	502
Not Malnourished	43.5	5.8	27.7	5028
Pre-maturity				
Born in time	44.1	6.4	29.2	5437
Premature	55.9	5.4	43.0	93
Breastfeeding duration (Months)				
Below 18	49.7	6.1	28.1	766
18-24	59.7	5.5	29.1	2017
24+	55.2	5.9	36.4	403
Still breastfeeding	35.9	7.3	28.9	2343
Maternal age (Years)				
Less than 20	37.7	8.4	28.2	308
20-24	43.8	5.1	27.4	1327
25-29	44.0	6.6	29.7	1530
30-34	46.5	6.9	30.7	1020
35+	44.8	6.5	30.2	1343
Area of residence				
Urban	34.9	6.2	24.2	828
Rural	45.9	6.4	30.3	1702
Zone				
Central	39.9	5.3	28.0	1195
Nothern	34.6	8.1	28.4	483
Coast	38.7	10.5	29.7	599
Southern	57.3	5.7	34.3	826
Southern Highland & West	49.7	5.5	31.4	1113
West Lake	39.0	4.9	22.1	992
Zanzibar	49.7	9.6	38.2	322
Maternal education				
No education	47.6	6.7	32.3	2192
Lower Education	46.7	5.5	32.2	758
Upper education	41.5	6.2	26.6	2403
Secondary/higher	29.9	7.9	19.8	177
Partner's education				
No education	46.5	7.4	32.0	1887
Lower Education	49.2	5.9	31.1	1032
Upper education	42.6	6.2	28.1	2579
Secondary/higher	34.4	5.4	23.8	425
Economic Status				
Better	38.9	6.0	24.5	1887
Poor	47.0	6.6	31.9	3643
Contraceptive use				
Ever used	38.9	6.2	25.4	1397
Never used	46.1	6.4	30.7	4133
Marital Status				
Married Polygamy	45.5	7.0	29.0	1291
Married Monogamy	44.2	6.1	29.5	3815
Never married/divorced/ widowed/separated	44.1	6.6	30.5	424
All	44.2	6.4	29.4	5530

¹ Children classified as **stunted** if height-for-age Z-scores are less than 2 SD from the median of the NCHS/CDC/WHO reference population.

² Children classified as **wasted** if weight-for-height Z-scores are less than 2 SD from the median of the NCHS/CDC/WHO references population.

³ Children classified as **underweight** if weight-for-age Z-scores are less than 2 SD from the median of the NCHS/CDC/WHO reference population

malnourished at the age 6 -11 months increased by 187 percent compared with the reference group of infants under 6 months old. This odd ratio rises to more than 8 after 36 months of age.

The next variable which has shown a marked change in effect of child nutritional status is area of residence. Results indicate that children living in rural areas have more chances of having malnutrition than their counterparts in urban areas. Zone 5, which comprises Mwanza, Mara and Kagera regions has the lowest chance of children being malnourished as compared with the reference category Zone 1. Zone 3, which constitutes Morogoro, Mtwara, Ruvuma and Lindi regions, has the highest percentage of relative effect for which the odds for children being malnourished is 127 percent more than for Zone 1. The reference group here labeled as Zone 1 consists of Dodoma, Arusha, Kilimanjaro, Singida, Tabora and Shinyanga, For key to zones see the footnote to Table3.

Maternal education, another variable which is significant for

explaining children's nutritional status. Results (Table 3) show that there is a decreasing chance for children to be malnourished as the educational level of their mothers improves. The odds of being malnourished among children whose mothers have acquired upper primary education decline by 18 percent from those whose mothers are not educated or attained only lower primary education

levels.

Table 3. Fitted coefficients of binary logistic regression model to predict stunting with standard errors, significance levels, odds ratios and percent of relative effect.

Coefficient	Estimate β_i	S.E of estimate	Significance ¹	Odds ratios ²	Percentage of relative effect ³
Overall mean	-2.6550	0.2613	Y	-	-
Area of residence					
Rural	0.0000	0.0000	-	1.00	-
Urban	-0.4779	0.0901	Y	0.62	-62
Zone					
Zone 1	0.0000	0.0000	-	1.00	-
Zone 2	0.3747	0.0916	Y	1.45	+45
Zone 3	0.8201	0.0928	Y	2.27	+127
Zone 4	0.4869	0.0834	Y	1.63	+63
Zone 5	-0.0162	0.0873	N	0.98	-2
Child's sex					
Male	0.0000	0.0000	-	1.00	-
Female	-0.2031	0.0578	Y	0.82	-18
Child's age (Months)					
Less than 6	0.0000	0.0000	-	1.00	-
6-11	1.0560	0.1582	Y	619	+187
12-23	2.0270	0.1416	Y	1258	+659
24-35	2.0150	0.1453	Y	1117	+650
36-47	2.1750	0.1544	Y	1009	+780
48-59	2.0940	0.1594	Y	958	+612
Preceding birth interval					
Less than 24 months	0.0000	0.0000	-	1.00	-
24 months and above	-0.2269	0.0846	Y	0.81	-19
First born	-0.2641	0.1170	Y	0.77	-23
Subsequent birth interval					
Less than 24 months	0.0000	0.0000	-	1.00	-
24 months and above	0.5645	0.1227	Y	1.76	+76
Last born	0.5063	0.1226	Y	1.66	+66
Maternal education					
No education/Lower Primary	0.0000	0.0000	-	1.00	-
Upper Primary	-0.1925	0.0682	Y	0.82	-18
Secondary/higher	-0.4648	0.1878	Y	0.63	-37
Pre-maturity					
Born in time	0.0000	0.0000	-	1.00	-
Premature	0.5621	0.2321	Y	1.75	+75
Birth status					
Single	0.0000	0.0000	-	1.00	-
Multiple	0.9642	0.2027	Y	2.62	+162
Maternal nutrition Status					
Malnourished	0.0000	0.0000	-	1.00	-
Not Malnourished	-0.2877	0.0999	Y	1.75	-25
Economic Status (radio ownership)					
Better	0.0000	0.0000	-	1.00	-
Poor	0.1754	0.0650	Y	1.19	+19
Contraceptive use					
Ever used	0.0000	0.0000	-	1.00	-
Never used	0.2250	0.0708	Y	1.25	+25
Maternal age (Years)					
Less than 20	0.0000	0.0000	-	1.00	-
20-24	-0.1998	0.1035	N	0.82	-18
25-29	-0.1758	0.1147	N	0.84	-16
30-34	-0.4867	0.1263	Y	0.61	-39
35+	-0.3244	0.1286	Y	0.72	-29

- ¹ Significant effect is determined by Wald Test if $[\beta_i / SE(\beta_i)] < 2$.

Variable categories classified as Y (yes) are significantly associated with child nutritional status while those classified as N (no) are not. (-) Reference variable category.

- ² Odds ratios are calculated by e^{β_i}
- ³ Percent of relative effects are calculated by $[1 - e^{\beta_i}] \times 100$
- ⁴ Zone
Zone 1- Dodoma, Arusha, Kilimanjaro, Singida, Tabora and Shinyanga
Zone 2 - Coast, Dar es Salaam, Tanga and Zanzibar
Zone3 - Morogoro, Mtwara, Ruvuma and Lindi
Zone4 - Iringa, Mbeya, Rukwa and Kigoma
Zone5 - Mwanza, Mara, and Kagera.

From this analysis, child's birth status has shown a pronounced effect on children's nutritional status. The odds of being malnourished for multiple births are 62 percent more than for singletons. In the case of prematurity, the odds of being malnourished among children born prematurely are increased by 75 percent compared with those born on time, while for those born to mothers who never used contraceptive, the odds of being malnourished are 25 percent higher than their counterparts. As expected from the literature, the chances of children being malnourished decrease as maternal age increases from 20 to 34 years.

Children born from women with malnutrition are more likely to be malnourished as well. Results on binary logistic regression analysis substantiate this fact by showing that maternal nutritional status has a significant effect on children's nutritional status. The odds of being malnourished for children whose mothers are not malnourished are 25 percent less than for those children whose mothers are malnourished. The last variable is the economic status of a household in which a child is residing. Children born to women whose households are economically poor, as measured by no radio ownership have increased odds of being malnourished compare to those children from richer households.

Discussion

Findings for the prevalence of short birth interval shows that as many as 15% of children are born within 24 months of their previous sibling. Furthermore, the odds of being malnourished for these children is 19 percent more than for those with a longer preceding birth interval. This finding is consistent with a recent study entitled "The Micro-consequences of High Fertility on Child Malnutrition in Mali," in which Laou and Mbacke (1992) on Demographic and Health Survey Data found that children born after a short birth interval (less than 24

months) run 2.32 times the risk of being malnourished compared to those born after 24 months. Findings on subsequent birth interval contrast with what was expected. If there is a long interval before a child is born, it could be expected that the older child may get proper nourishment and care as compared with a child with a short succeeding birth interval. Intuitively, this is due to the fact that care and attention from the mother is shifting to a new born child while the former still need it. This is substantiated by the results of this study that, the odds of being malnourished for children with a subsequent birth interval of 24 months and more are increasing by 76 percent as compared to those with less than 24 months. Since this is the first attempt to examine the effect of subsequent birth interval on children's nutritional status thus, further studies are required to prove these results.

Demographic factors play a significant role in determining nutritional levels. Apart from birth intervals, another explanatory variable which was observed to be linked with child malnutrition was the age of a child. Our findings show that a child's chances of being malnourished are 187 percent higher than for younger infants. This rises to 712 percent when children are at age 48-59 months, again compared with the reference group of infants aged 0-6 months. There is also a sex differential on the chances of having malnutrition among children under five years of age. The relative effect of the child's sex on the odds of malnutrition are such that a boy is 18 percent more likely to be malnourished than a girl, after controlling for other factors. These results are diluted version of those found in Mali where the chance of a male child being malnourished are twice as high as that for a female child.

Turning to the effect of maternal factors, the nutritional status of a child is linked to that of its mother. There is a higher risk of malnutrition for children born to a mother who is malnourished than from a well nourished mother. These results substantiate findings in the descriptive analysis, which show that prevalence of malnutrition among children born with malnourished mothers is higher than among those ones whose mothers are not malnourished. Results on the levels of maternal education show that there is a significant decrease of the chance of children being malnourished as their mothers' levels of education shift from no education to secondary school and higher education. The odds of being malnourished for children whose mothers have attained upper primary education decrease by 18 percent from those whose mothers attained only lower primary education or were uneducated. The odds decrease by twofold as mothers attain secondary school and higher education. This finding supports the large and increasing literature on the importance of maternal education for child health. Maternal age too has often been related to infant and child mortality. Teenage and old women are experiencing higher

infant and child mortality than their counterparts from the middle ages. In Tanzania, the differential in mortality between the children of teenagers and those of 35 years odds is twofold. Our findings on the effect of maternal age on children's nutritional status comply with this pattern and it is not surprising to recall that malnutrition is one of the most important causes of child mortality in Tanzania. The chance of children being malnourished declines as maternal age increases. From our analysis at maternal age 20-24 years (this is the mother's age at the time of the child's birth), the odds of children being malnourished are 18 percent less than for children born when their mothers are teenagers. The odds of a child being malnourished are almost halved when the age of the mother at birth is 30-34 years compared with those of a child of a teenage mother.

The influence of the household's economic status on nutritional status of the children suggests that nutritional status is not only dependent on the spacing of deliveries but also on the financial status of the households where they reside. In this analysis, we used radio ownership as a proxy for household economic status. Findings show that for children whose household are poor as measured by this proxy, the odds of being malnourished are 1.19 times higher than those whose households are economically better off. The findings make sense due to the fact that economically better off households have enough resources to guarantee consistent nourishment and care to their children.

The use of contraceptive among women was observed to play a significant role on the effect of children's malnutrition. The prevalence of current use and ever use of any method of contraception is about 10 percent and 23 percent in Tanzania respectively. These are among the lowest rates among sub-Saharan African countries. In our analysis, ever use of contraception exert a significant impact on children's nutritional status. Finally, children born in multiples have the characteristics of having low birth weight which in most cases is positively associated with poor nutritional status among children under five years of age. Results on the relative effects of birth status on children's nutritional status show that, the odds of getting malnutrition increase by 162 percent for those born multiple as compared to those born single. Similarly, for those premature births the odds of being malnourished increased by 75 percent as compared to those born on time.

Conclusion

The study attempted to analyse the effect of birth interval on children nutrition status by laying down the hypothesis that a child born after a short birth interval is more likely to be malnourished since the existence of an older sibling of a slight similar age may cause competition for resources and propagation of contagious diseases among them.

Maternal depletion syndrome which is positively related to the short birth interval may also result in poor nutritional status of their children. Results show that birth interval has a strong effect on children nutritional status. However, in due process of affecting nutritional status, the birth interval effect is accompanied by other explanatory variables such as maternal education, maternal nutrition, economic and birth status. Other accompanied effects are; area of residence, maternal age, sex and age of child, use of contraceptives and geographical zones.

The existence of differential prevalence of malnutrition on the basis of zonal and area of residence classified as rural and urban areas reflects the difference of social and economic development prevailing in the country. Low prevalence of malnutrition among children in the northern zone is largely contributed by better communication, a higher quality of education and low level of poverty among families compared to other areas, particularly the southern and western zones and southern highlands.

A larger percent of women who give birth at an interval of 24 months and more typically reflects an in-built nursing culture of breast feeding for a long duration in the country. Despite the known advantages of breast milk as an ideal nutritional food source for babies and young children, breast-feeding was not a significant influence on children's nutrition status in our analysis. This might be because of the counteracting effects of poor economic status and low level of education among those women who breast feed for a long time. Patterns of supplementation when babies are weaned may well be deficient, where resources are scarce. Breast feeding duration as a variable is also made difficult to interpret because of the way we define birth interval as an interval between consecutive live births. This implies that still births and abortions that have occurred between intervals are not considered in this analysis. If still births and abortions could be taken into consideration, there might be a higher prevalence of short birth intervals among children. However, the first round of the Tanzania Demographic and Health Survey did not collect such information. Despite this limitation, birth intervals remain to be a strong determining factor for nutritional status of children.

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