# Continue



The chibuku beer consumed in southern Africa is basically a thin fermented porridge, usually made from sorghum.

**Breads and other baked products**

Flat breads are made by baking batters made with flour and water on a hot pan or griddle. Almost any flour may be used. The batter can be based on sorghum, millet or any other cereal and it may or may not be fermented. These flat breads are known by many local names: roti and charpatti in India, tuwo in parts of Nigeria, tortillas in Central America, etc.

Unfermented breads include roti and tortillas. Roti and chapatti made from sorghum or millets are common foods in India, Bangladesh, Pakistan and Arab countries. More than 70 percent of sorghum grown in India is used for making roti (Murty and Subramanian, 1982).

Tortillas, which are prepared in Mexico and Central America, are similar to roti except that the grain is lime-cooked and wet milled. Although corn is the preferred grain for making tortillas, sorghum is widely used and is well accepted in Honduras (Dewalt and Thompson, 1983). Sometimes tortillas are made by mixing sorghum and corn. White sorghum is the preferred sorghum for making tortillas. Sorghum can be dehulled to reduce the off-white colour of the product. Tortillas prepared from blends of yellow maize and pearled sorghum (15 percent) had lighter colour than 100 percent yellow maize tortillas and were found acceptable (Choto, Morrad and Rooney, 1985). Sorghum cultivars Dorado, Sureno and Tortillero from Central America and two hybrids from the Texas Agricultural Experiment station gave tortillas with the best colour and texture (Almeida-Dominguez, Serna-Saldivar and Rooney, 1991). Sorghum kernels with thick white pericarp and yellow endosperm from plants with tan colour and straw-coloured glumes have excellent potential for the manufacture of tortillas.

**TABLE 32: Proximate composition of maize and sorghum ogi obtained from study villages[a]**

| Type of ogi | Moisture (g) | Protein (g) | Fat (g) | Crude fibre (g) | Carbohydrate (g) | Ash (g) | Energy (kcal) | Protein energy (%) |
|---|---|---|---|---|---|---|---|---|
| Per 100 g wet weight | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Maze | 54,01,9 | 3,50,2 | 2,20,2 | 0,20,1 | 39,82,1 | 0,30,1 | 193,07,4 | 7,20,5 |
| Sorghum | 68,24,6 | 4,40,1 | 1,70,1 | 0,90,2 | 24,24,2 | 0,70,1 | 129,518,5 | 13,81,9 |
| Per 100 g dry weight | | | | | | | | |
| Maze | 7,60,5 | 4,80,5 | 0,40,1 | 86,51,0 | 0,60,3 | 420,02,7 | | |
| Sorghum | 14,01,9 | 5,40,4 | 2,90,2 | 75,62,1 | 2,10,1 | 406,90,1 | | |

**a Mean SD.**
***Source:* Brown et al., 1988.**

**Injera (Ethiopia) and kisra (the Sudan) are the major fermented breads made from sorghum flour (Gebrekidan and Gebre Hiwot, 1982). Teff is the preferred cereal for injera preparation. However, sorghum and teff can be mixed, and sorghum alone is also often used. The quality of injera is determined in part by the extent of fermentation. In general, children are given lightly fermented injera with mild sourness. Kisra is a traditional and staple food of the Sudan, prepared from sorghum and millet (Bad), Bureng and Monawar, 1987). It is made with a fermentation starter which shortens the time required for fermentation to less than 16 hours (Bad), Bureng and Monawar, 1988).**

**A comparison of sorghum and millet flours and bread (roti) made from them (Tables 33 to**

**35) indicated that baking did not affect the chemical composition including the fatty acids (Khalil et al., 1984; Sawaya, Khalil and Safi, 1984). A slight increase in tyrosine, lysine and methionine content was observed when sorghum flour was made into fermented bread. Baking at 300C for 15 minutes decreased arginine, cystine and lysine content in pearl millet bread.**

**Eggum et al. ( 2983) compared the nutritional quality of sorghum grain and kisra made from it. Sorghum is deficient in lysine and therefore has a low biological value. On the other hand, the true digestibility of protein, as well as digestible energy, is very high, with values above 90 percent. Variety was observed to have only a minor influence on the nutritional quality of kisra when preparations from several sorghum varieties were compared (Tables 30 and 31).**

**Many studies have been done to explore the potential for making loaf bread with composite flours that include either sorghum or millet, and there are no technical difficulties in using any of these flours. Casey and Lorenz (1977) reported that a breed made with part millet flour had excellent texture and a flavour similar to that of whole wheat bread. There is always a steady deterioration of bread quality as the percentage of non-wheat flour is increased. If the flour is coloured (as is the case with pearl millet and abrasively decorticated sorghum that contains too many brown sorghum seeds), it is usually the extent of discoloration that limits the amount of non-wheat flour that can be used. In most other cases the limiting factor is the density of the loaf. Unless other**

**additives (usually expensive imports) are used, about 10 percent of non-wheat flour is the limit most people will accept, although many reports have claimed that breads made using much higher rates of addition were acceptable. Cakes and biscuits can be made using flour with much higher levels of non-wheat flour, but again, as with bread, the quality of the product deteriorates as the substitution level increases. Composite flour has been used commercially in bread in several countries, but it is usually accepted only when there is a shortage of wheat flour, and even then unwillingly.**

**TABLE 33: Proximate composition and tannin content of sorghum flour and bread[a]**

| **Product** | **Moisture (%)** | **Crude protein (Nx6.25)** | **Crude fat (% )** | **Crude fibre (%)** | **Ash (%)** | **Carbohydrate (by difference) (%)** | **Tannins[b] (%)** |
|---|---|---|---|---|---|---|---|
| Flour | | | | | | | |
| White sorghum | 12.4 | 15.3 | 4.7 | 2.3 | 2.2 | 75.5 | 0.09 |
| Reddish-white sorghum | 12.1 | 15.9 | 5.1 | 2.5 | 2.3 | 74.2 | 0.27 |
| Bread | | | | | | | |
| White sorghum | 27.2 | 15.7 | 4.0 | 2.5 | 2.5 | 75.3 | 0 |
| | | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Reddish-while sorghum | 32.2 | 16.2 | 5.1 | 2.4 | 2.4 | 73.9 | 0 |
| Reddish -white sorghum, fermented | 35.4 | 16.4 | 4.9 | 2.9 | 2.2 | 73.6 | 0 |

**a Means of duplicate determinations (variaton < 5%) expressed on dry-weight basis. except moinsture which was determined in fresh samples.**
**b Expressed as catechin equivalents (CE)**
***Source*: Khalil et al., 1984.**

**TABLE 34: Mineral composition of sorghum flour and bread (mg %)[a]**

| **Product** | **Na** | **K** | **Ca** | **P** | **Mg** | **Fe** | **Zn** | **Cu** | **Mn** |
|---|---|---|---|---|---|---|---|---|---|
| **Flour** | | | | | | | | | |
| White sorghum | 21 | 458 | 18 | 396 | 54 | 5.0 | 3.3 | 0.8 | 3.5 |
| Reddish-white sorghum | 23 | 463 | 16 | 407 | 58 | 4.5 | 3.2 | 0.7 | 3.4 |
| Bread | | | | | | | | | |
| White sorghum | 133 | 308 | 30 | 259 | 49 | 5.4 | 2.4 | 0.6 | 2.6 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Reddish -white sorghum | 160 | 308 | 23 | 256 | 54 | 5.0 | 2.3 | 0.6 | 2.3 |
| Reddish-white sorghum, fermented | 174 | 300 | 27 | 187 | 57 | 4.2 | 2.5 | 0.7 | 2.8 |

**a Means of duplicate determinations (variation < 5% ) expressed on dry-weight basis.**
***Source*: Khalil et al., 1984.**

**TABLE 35: Proximate compositions and tannin content of pearl millet flour and bread[a]**

| **Product** | **Moisture (%)** | **Crude proteine (Nx6.25)** | **Crude fat (%)** | **Crude fibre (%)** | **Ash (%)** | **Carbohydrate (by difference) (%)** | **Energy (kcal/100g)** | **Tanins (%)** |
|---|---|---|---|---|---|---|---|---|
| Flour | | | | | | | | |
| As-is basis | 9,7 0,8 | 15,70,3 | 5,70,2 | 2,50,7 | 2,0+0,1 | 64,42,1 | 37210,5 | 0,170,05 |
| Dry basis | | 17,4 | 6,3 | 2,8 | 2,2 | 71,3 | 412 | 0,19 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Bread | | | | | | | | |
| As-is basis | 26,6+1,5 | 12,70,4 | 4,10,2 | 2,10,3 | 1,90,2 | 52,61,8 | 2999,2 | 0 |
| Dry basis | | 17,3 | 5,6 | 2,8 | 2,6 | 71.9 | 407 | 0 |

**Pasta and noodles**

**Pasta products (noodles) such as spaghetti and macaroni are usually made from semolina or from flour of durum wheat or common wheat or a mixture of both. Wheat has a unique property of forming an extensible, elastic and cohesive mass when mixed with water. Sorghum and millet flours lack these properties when used alone.**

**Sorghum is inferior to wheat for making pasta, both because it contains no gluten and because its gelatinization temperature is higher than that of wheat. Miche et al. (1977) made pasta from mixtures of sorghum with wheat. They found that to obtain products of good cooking quality it was necessary to add some gelatinized starch to the sorghum flour before extrusion. The pasta quality is influenced by the quality of both the sorghum flour and the starch. White sorghum is preferable for pasta products as its colour is similar to that of wheat flour. A composite flour consisting of 70 percent wheat and 30 percent sorghum produced acceptable pasta.**

Noodles made with 20 percent prove millet flour were acceptable (Lorenz and Dilsaver, 1980). The reduction of flour mass during cooking (cooking loss) at this level of addition was similar to that of wheat noodles used as a control. Cooking loss increased with 40 or 60 percent millet flour.

Faure (1992) made pasta from mixtures of sorghum, millet and wheat. He found that the quality of the pasta was strongly related to the characteristics of the flour that was used and particularly to the way the flour was dried. There should be less than I percent ash and I percent fat in any material that is used. Proper hydration is necessary. Regrinding and intensive shearing during mixing and extrusion improves hydration. It is difficult to hydrate large pieces of corneous endosperm.

Desikachar ( 1977) prepared noodles by extruding boiled sorghum dough through a press and then steaming and drying it. In China, sorghum noodles are made using a special device.

## Weaning foods

Germinated sorghum flour, called "power flour" (kimea in the United Republic of Tanzania), reduces the viscosity of the food product. It is thus possible to use double the quantity of flour to make a product of similar consistency, so the energy density of weaning foods can be increased (Seenappa, 1988). Sorghum and millets are used in

**weaning foods in countries such as Ethiopia, India, the United Republic of Tanzania and Uganda. Seenapa (1988) described sorghum and millet weaning foods that are being promoted in a number of African countries.**

**Use of sorghum- and millet-based weaning foods prepared using extrusion and malting techniques has been found successful. These foods have been promoted as high-energy or high-protein foods but would have better acceptance and be more popular if the cost could be reduced.**

**The quality of weaning foods prepared from cowpea and malted or rollerdried sorghum was evaluated (Malleshi, Daodu and Chandrasekhar, 1989). The weaning food formulation based on malted sorghum and malted cowpea was nutritionally superior to roller-dried weaning food prepared using the unmelted raw materials. The available lysine content was 3.85 percent in the malted food and 2.95 percent in roller-dried sorghum food. The protein efficiency ratio of malted food was 2.26, significantly higher than that of the roller-dried food ( 1.87). The cooked paste viscosity of malted sorghum was considerably lower than that of the roller-dried sorghum.**

**Traditional beverages**

**Though beverages are not major foods, they serve as a source of energy in several countries. Thin fermented porridges are commonly prepared and used as a drink in African**

**countries. They are considered foods and provide important nutrients. Traditional beer, amgba, and a wine, affouk, prepared from sorghum in Cameroon were found to be nutritionally superior to sorghum flour (Chevassus-Agnes, Favier and Joseph, 1976) as they provide additional riboflavin, thiamine and lysine. Derman et al. (1980) found that iron absorption from maize and sorghum beer was more than 12 times higher than that from the constituents that were used to prepare the beer. In traditional sorghum beer, most of the thiamine and about half of the riboflavin and niacin are associated with beer solids which contain the yeast (van Heerden and Glennie, 1987). The beer with the highest total solids contained the highest amounts of minerals and trace elements (van Heerden, Taylor and Glennie, 1987). Thus the beer is a source of vitamins, iron, manganese, magnesium, phosphorus and calcium. The beer contained 26.7 g starch and 5.9 g protein per litre.**

**Lager beer can also be produced from sorghum. In Nigeria, sorghum has been tested as a barley malt substitute for producing beer (Obilana, 1985). Beer has been produced successfully by blending equal amounts of sorghum and barley. Lager beer was brewed from sorghum malt using the three-stage decoction method and 30 percent sucrose as an adjunct (Okafor and Aniche, 1987). In Rwanda, a new type of beer is produced using local sorghum and barley (lyakaremye and Twagirumukiza, 1978). Up to 40 percent sorghum mixed with barley malt makes acceptable beer.**

**Amylopectin starches are not suitable for lager as they cause difficulty in filtration. Varieties with low starch gelatinization temperature may be suitable. Good malting barley**

**or cereal usually has white floury or starchy endosperm. Similarly, sorghum with predominantly floury endosperm is preferred for malting. Sorghum and corn grits are similar in amino acids, proteins and starch composition (Canales and Sierra, 1976), and sorghum may confer additional oxidative stability because of its fatty acid composition.**

**Distilled alcohol can also be produced with suitable modifications and sorghum may have good potential in the industry. Distilled spirits are produced from sorghum in China, where the alcoholic beverage industry is a major consumer of sorghum grain.**

**Traditional opaque beer, for which sorghum and millets are valuable raw materials, is a popular beverage in several countries in Africa. It is called chibuku in Zimbabwe, impeke in Burundi, dolo in Mali and Burkina Faso and pito in Nigeria. The main attributes of this product are short shelf-life of about one week, low alcohol content, acidic nature, suspended solids and a characteristic taste and colour (Chitsika and Mudimbu, 1992). Opaque beer is more a food than a beverage. It contains high proportions of starch and sugars, besides proteins, fat, vitamins and minerals. In its manufacture white sorghum with less polyphenols is preferred, although red and brown sorghum varieties are also used. Red sorghum imparts a pinkish-brown colour to the beer. Hightannin sorghum is not desirable for beer production. The malt used for the manufacture of beer should have high diastatic activity and solubility. Malts are also sources of lactobacilli and essential nutrients.**

**Extruded products**

**Extrusion is being used increasingly often for the manufacture of snack foods. In extrusion processes, cereals are cooked at high temperature for a short time. Starch is gelatinized and protein is denatured, which improves their digestibility. Antinutritional factors that are present may be inactivated. Microorganisms are largely destroyed and the product's shelf-life is thereby extended. The products are easily fortified with additives.**

**So far, sorghum and millet extrusion products have not yet been produced on a commercial scale. Fapojuwo, Maga and Jansen ( 1987) used two low-tannin sorghum varieties in extrusion studies. Extrusion improved the digestibility of one variety from 45.9 to 74.6 percent and of the other from 43.9 to 68.2 percent. The cooking temperature was the variable that most influenced digestibility. Youssef et al. ( 1990) used two varieties of sorghum (one brown, one white) to make 16 different extrusion products. The proportion of sorghum in the formulations ranged from 45 to 97 percent. These studies showed that sorghum can be used with other cereals to make acceptable extruded products.**

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# Improving nutritional quality

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No one legume or cereal can provide adequate amounts of all nutrients to meet the nutritional requirements of a child. However, even before knowledge on protein content, protein quality, digestibility and the nutrient requirements of humans became available, it was recognized that mixing legumes with cereals in the diet could improve overall nutrition. The present and newly derived knowledge in these areas makes it possible to blend, mix or fortify one food material with others so that the resulting fortified mix has not only better nutritional quality but also the necessary attributes for consumer acceptance.

The nutritional quality of sorghum and millets, especially the former, is poor. Therefore attempts have been made to fortify these cereals with legumes or other cereals to make nutritionally superior and acceptable products. Cost, availability of ingredients and marketability must be taken into consideration if fortification is to be implemented successfully on a sustained basis.

Sorghum and pearl millet have been successfully used in feeding programmes after fortification with legumes. Vimala, Kaur and Hymavati (1990) described various infant mixes based on sorghum and pearl millet and fortified with soybean, green gram, red

**gram or Bengal gram flour (Table 36). They were evaluated through rat feeding trials and nitrogen balance studies in children.**

**It is possible to fortify malted finger millet (rug)) weaning food with green gram. The food has the advantage of having low cooked paste viscosity and has high energy density when mixed in the proportion of 70 percent malted ragi flour and 30 percent green gram flour. The NPU of this food was observed to be 52 percent and was comparable to that of a commercially available weaning food (Malleshi, Desikachar and Venkat Rao, 1986).**

**Okeiyi and Futrell ( 1983) evaluated the protein quality of various combinations of sorghum with cereals and legumes. These included (dehulled) sorghum, wheat and soy flours; sorghum, wheat, cowpea and soy flours; sorghum, wheat and cowpea flours plus peanut butter; sorghum and wheat flours plus peanut butter; and sorghum, wheat and soy flours plus peanut butter. A diet of sorghum, wheat and soy flours met the FAO recommendations for required amino acids. Over 25 percent of the energy of this diet was provided by fat and 10 percent of the energy was provided by protein as recommended by the United Nations Protein Advisory Group for the formulation of high-protein foods for children. The diet had the same high PER as casein.**

**TABLE 36: Formulations tested and developed for adoption in feeding programme (millet and pulse mixes)**

| Ingredients | Proportion |
|---|---|
| Sorghum *rawa* (semolina): soybean flour: skim milk powder | 70:25:5 |
| Sorghum *rawa*: soybean flour: sugar | 70:10:20 |
| Sorghum flour: pigeon pea flour | 80:20 |
| Pearl millet flour: green gram flour | 70:30 |
| Pearl millet flour: black gram flour | 70:30 |
| Pearl millet flour: Bengal gram flour | 70:30 |

***Source*: Vimala, Kaur and Hymavati, 1990.**

**Brookwalter, Warner and Anderson (1977) evaluated the stability of sorghum fortified with soy and cottonseed flour in different proportions. The various formulations were stored at -18C (control), 49C for two months, 37C for six months and 25C for 12 months. All combinations displayed adequate stability as measured by change in available lysine, stat, acidity and flavour. The flavour of all blends was acceptable.**

**In Burundi, sorghum fortified with maize and soy flours, locally known as musalac, has been used as a baby and adult food. It has the following composition: 35 percent sorghum flour, 30 percent maize flour, 20 percent soybean flour, 10 percent sugar and 5 percent milk powder. This combination has about 16 percent protein, with 3.76 percent of protein**

**contributed by lysine and 440 kcal per 100 g of product. Musalac is very popular; 60 l/month were sold commercially in 1989, and production is expected to reach 9 000 tonnes by the year 2000.**

**TABLE 37: Mean protein intake and net available protein in children on different diets**

| Diet | Protein intake | | Net available protein | | FAO reference protein requirements[a] |
|---|---|---|---|---|---|
| | (g) | (g/kg) | (g) | (g/kg) | |
| Finger millet | 29.7 | 1.31 | 13.5 | 0.60 | 0.72 |
| Finger millet + L-lysine | 29.9 | 1.32 | 15.8 | 0.70 | 0.72 |
| Finger millet + L-lysine | | | | | |
| + DL-threonine | 30.4 | 1.35 | 18.0 | 0.80 | 0.72 |
| Skim milk powder | 28.3 | 1.25 | 21.2 | 0.94 | 0.72 |

**a From FA0, 1965.**

***Source*: Daniel et al., 1965.**

**The quality of a ragi diet was evaluated by feeding it to eight 11 - to 12-yearold girls in Mysore, India (Daniel et al., 1965). In addition to ragi, the diet included peanut oil, red gram dhal, condiments and skim milk powder. After the diet was followed for four days as acclimatization period, material was collected for analysis during the next four days. The retention of nitrogen on the finger millet diet was very low (6.1 percent of intake) and the biological value (BV) and net protein utilization (NPU) were 67.0 and 45.5 percent respectively (Table 37). Supplementation of the finger millet diet with L-lysine caused a significant improvement in nitrogen retention (13.6 percent of intake), BV (75.9 percent) and NPU (52.7 percent). When the ragi diet was supplemented with both L-lysine and DL-threonine, highly significant improvements in the nitrogen retention (21.3 percent of intake), BV (8 1.2 percent) and NPU (59.3 percent) were observed. The corresponding values obtained for skim milk powder were 33.2,85.3 and 74.8 percent, respectively. Net available protein showed good improvement on supplementation with Iysine and threonine.**

**Supplementing various types of millets with chickpea has shown good improvement in the protein efficiency ratio as shown in Table 38 (Casey and Lorenz, 1977).**

**TABLE 38: PER of diets based on millets or blends of millet and chickpea a**

| Protein source | PER |
|---|---|
| Foxtail millet | 0.80 |
| Proso millet | 1.10 |
| Proso millet + chickpea | 1.80 |
| Pearl millet | 1.60 |
| Pearl millet + chickpea | 2.16 |
| Finger millet | 2.00 |
| Finger millet + chickpea | 2.10 |
| Rice | 2.09 |
| Whole wheat | 1.30 |

**a Protein content in diet: 10 percent. As a supplemental protein source. chickpea provided 40 percent of protein**
***Source*: Casey and Lorenz, 1977.**

**Composite flours**

**Composite flour technology initially referred to the process of mixing wheat flour with**

**cereal and legume flours for making bread and biscuits. However, the term can also be used in regard to mixing of non-wheat flours, roots and tubers, legumes or other raw materials (Dendy, 1992). One example is the mixture of sorghum and maize flour for tortillas.**

**Diluting wheat flour with locally available cereals and root crops was found to be desirable to encourage the agricultural sector and reduce wheat imports in many developing countries. In Africa there has been an ever-increasing demand for wheat products such as bread. Africa is not a major wheat-growing region, but it produces large quantities of other cereals such as sorghum and millets. It has been reported that replacing wheat with 20 percent non-wheat flour for the manufacture of bakery products would result in an estimated savings in foreign currency of US$320 million annually (FAO, 1982). At 30 percent substitution the savings would be US$480 million annually. Thus composite flour technology holds excellent promise for developing countries. Although actual consumer trials have been rare, products made with composite flour have been well accepted in Colombia, Kenya, Nigeria, Senegal, Sri Lanka and the Sudan (Dendy, 1992).**

**When sorghum or millets are used for bread-making, addition of bread improvers or modification of the bread-making process is needed. A higher level of substitution is possible with hard than with soft wheat flour (United Nations Economic Commission for Africa, 1985). For the production of biscuits from composite flours, the fat content of the**

**non-wheat flour should be kept as low as possible to promote a longer shelf-life.**

**Crabtree and Dendy (1979) reported that bread could be produced from composite flour made by co-milling wheat with pearl, prove, barnyard or finger millets. The proportion of millet in the flour can be up to 15 percent. Potassium bromate treatment of the dough tends to improve the loaf volume. Bread containing I 0 percent pearl millet flour had an excellent texture and flavour similar to that of whole-wheat bread (Bad), Hoseney and Finney, 1976; see also Perten, 1972).**

**Sorghum flour milled at 80 percent extraction rate could be blended with white wheat flour for bread-making without any adverse effect (Rao and Shurpalekar, 1976). Acceptability studies conducted at the Food Research Centre in Khartoum, the Sudan, indicated that breads made with composite flour of 70 percent wheat and 30 percent sorghum were acceptable. Milling at 72 to 75 percent extraction rate yielded fine sorghum flour that is more suitable for bread-making. Consumer acceptance trials in Nigeria indicated that breads made with 30 percent sorghum flour were comparable to 100 percent wheat bread (Aluko and Olugbemi, 1989; Olatunji, Adesina and Koleoso, 1989). The protein content of composite flour was lower than that of wheat flour, while its crude fibre was higher. Addition of pentosan improved the quality of bread made with composite flour. The Institute of Food Technology in Dakar, Senegal, prepared a bread consisting of 30 percent millet and 70 percent wheat using the popular millet varieties Souna and Sanio (Thiam,1981). Another bread, called panble, was prepared with 15**

**percent millet and 85 percent wheat. Bread with 30 percent sorghum and 70 percent wheat was also prepared in Senegal (Thiam and Ndoye, 1977). Breads with up to 15 percent prove millet were acceptable and comparable to white wheat bread (Lorenz and Dilsaver, 1980).**

**A combination of 80 percent non-wheat cereal and 20 percent wheat can be used to produce biscuits with acceptable quality. Sorghum and pearl millet flour blended with wheat flour can be used to make biscuits (Badi and Hoseney, 1976, 1977). Olatunji, Adesina and Koleoso ( 1989) reported that a proportion of 55 percent sorghum could be used for biscuits without adversely affecting biscuit quality. Proso millet was found suitable for making biscuits; biscuit spread and quality score increased with increased levels of prove millet flour because of its high fat content (Lorenz and Dilsaver, 1980). Millet flour imparted a slight grittiness, however. Pearl millet could replace 50 percent of the wheat for cake and 80 percent for biscuits (Thiam, 1981). In Senegal, traditional foods such as faux, conus conus and beignets (fritters) are prepared by mixing millet flour with rice, maize or wheat flour (Thiam, 1981).**

## Alternative uses of sorghum and millet

**Sorghum and pearl millet production has considerably increased in several countries during the past few years. With the simultaneous increase in the production of wheat and**

**rice and the available surplus in storage, millets face competition from the utilization point of view. There is already an increasing trend of using wheat or rice in place of sorghum even in those regions where sorghum has been the traditional staple grain in the past.**

**Sorghum and millets will continue to be major food crops in several countries, especially in Africa (and in particular in Nigeria and the Sudan, which together account for about 63 percent of Africa's sorghum production). These grains will be used for traditional as well as novel foods. However, there is a need to look into the possibilities of alternative uses. Though sorghum and millets have good potential for industrial uses, they have to compete with wheat, rice and maize. Sorghum in particular could be in great demand in the future if the technology for specific industrial end uses is developed. Although pearl millet has some potential for industrial use, other millets have limited potential because of their small grain size and the associated difficulties of adopting a suitable dehulling technology. However, they can be considered for animal and poultry feed. There is a need to compare their performance as feed in comparison with maize.**

**Sorghum and millets can be adopted for other food products by using appropriate processing methods. Dehulling and milling practices to improve the quality of foods made from sorghum and millets have been described in Chapter 3. It may be possible to select grain types with improved milling quality that will make these crops competitive with other cereals in terms of utilization. Wheat milling technology with suitable modification**

**can be effectively used for grinding sorghum and millets. Although bread can be produced from whole sorghum flour, the quality of the bread can be improved by using sorghum flour from which the bran fraction has been removed by passage through sieves (Caster et al., 1977). Kulkarni, Parlikar and Bhagwat ( 1987) reported that sorghum malt could be used to make biscuits, weaning foods and beer wort. Addition of up to 40 percent sorghum malt in biscuits caused reduction in stack height and increase in spread because of increased water absorption.**

**The use of sorghum in common foods such as idli (a steamed product), dosa (a leavened product) end ponganum (a shallow-fat-fried product) can be popularized for wider use in sorghum-growing areas (Subramanian and Jambunathan, 1980). A few important sun-dried or extruded and sun-dried products from sorghum are papad, badi and kurdigai. These products usually have a shelf-life of over one year. They can be popularized through marketing channels similar to those used for rice products. A wide range of bakery and snack products prepared with dehulled sorghum were accepted by consumers in Andhra Pradesh, India (Andhra Pradesh Agricultural University, 1991). It was indicated that these foods should be marketed commercially to make them reach more people and become more popular.**

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# Chapter 6 - Nutritional inhibitors and toxic factors

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**As with other foodstuffs certain nutritional inhibitors and toxic substances are associated with sorghum and millet grains. Antinutritional factors can be classified broadly as those naturally present in the grains and those due to contamination which may be of fungal origin or may be related to soil and other environmental influences. These factors modify the nutritional value of the individual grains, and some of them have very serious consequences. The following is a brief account of some of the antinutrients and toxic substances associated with sorghum and millets.**

## Phytate

**Phytate represents a complex class of naturally occurring phosphorus compounds that can significantly influence the functional and nutritional properties of foods. Although the presence of these compounds has been known for over a century, their biological role is not completely understood. Phytic acid, myo-inositol 1,2,3,4,5,6-hexakis(dihydrogen**

**phosphate), is the main phosphorus store in mature seeds. Phytic acid has a strong binding capacity, readily forming complexes with multivalent cations and proteins. Most of the phytate-metal complexes are insoluble at physiological pH. Hence phytate binding renders several minerals biologically unavailable to animals and humans.**

**Doherty, Faubion and Rooney (1982) analysed several varieties of sorghum and found that in the whole grain phytin phosphorus ranged from 170 to 380 mg per 100 g; over 85 percent of the total phosphorus in the whole grain was bound as phytin phosphorus. Wang, Mitchell and Barham ( 1959) studied the distribution of phytin phosphorus in sorghum grain and found that a greater percentage of physic acid was in the germ than in the bran and the least was in the endosperrn. Dehulling can remove 40 to 50 percent of both phytate and total phosphorus. It was observed that phytin phosphorus constituted 82 to 91 percent of total phosphorus in the whole grain, 56 to 84 percent in the dehulled grain and 85 to 95 percent in the bran. In the fractions obtained through traditional milling, phytin phosphorus content was greatest in the bran, less in the whole grain and lowest in the dehulled grain. This suggested that the bran and aleurone layers of the grain are a major reservoir of phytate and total phosphorus in sorghum. As milling of soft-endosperm varieties removes only a small amount of pericarp, milling causes less decrease in phytin phosphorus in these varieties. Bioavailability of iron in sorghum for human subjects was found to be affected more by phytin phosphorus than by tannin content of the grains (Radhakrishnan and Sivaprasad, 1980). On pearling of sorghum grain, a significant increase in ionizable iron and soluble zinc content indicated improved**

**bioavailability of these two micronutrients, which was attributed partially to the removal of phytate, fibre and tannin along with the bran portion during pearling (Sankara Rao and Deosthale, 1980).**

**In pearl millet, values reported for phytin phosphorus varied from 172 mg per 100 g (Sankara Rao and Deosthale, 1983) to 327 32 mg per 100 g (Chauhan, Suneja and Bhat, 1986). The values reported by Simwemba et al. (1984) were within this range. Ionizable iron was inversely correlated and soluble zinc negatively correlated with phytin phosphorus. Sankara Rao and Deosthale (1983) further observed that malting of the grain significantly reduced the phytin phosphorus content of both pearl and finger millets. This decrease was accompanied by significant increases in ionizable iron and soluble zinc, indicating improved bioavailability of these two elements. Germination of finger millet varieties progressively decreased phytin phosphorus content of the grain (Udayasekhara Rao and Deosthale, 1988). After 48-hour germination with removal of the vegetative portion, the total phosphorus in malted grains decreased by 16, 12 and 9 percent in pearl, finger and foxtail millet, respectively (Malleshi and Desikachar, 1986b). Phytin phosphorus decreased significantly from 38 to 20 percent on germination of pearl millet. However, in finger and foxtail millets the decrease in phytin phosphorus was very small. A weaning food based on germinated wheat, pearl millet, chickpea, mung bean and sesame contained only 4.39 mg phytin phosphorus per 100 g, as against I 0 mg per 100 g in the mix prepared from ungerminated grain (Nattress et al., 1987). In a fermented Indian preparation of pearl millet known as rabadi, the phytin phosphorus after nine-hour**

**fermentation had decreased by 27 to 30 percent ( Dhankher and Chauhan, 1987).**

## Polyphenols

**Widely distributed polyphenols in plants are not directly involved in any metabolic process and are therefore considered secondary metabolites. Some polyphenolic compounds have a role as defence chemicals, protecting the plant from predatory attacks of herbivores, pathogenic fungi and parasitic weeds. Polyphenols in the grains also prevent grain losses from premature germination and damage due to mould (Harris and Burns, 1970, 1973). Dreyer, Reese and Jones ( 1981) observed that polyphenols protect seedlings from insect attack.**

**Phenolic compounds in sorghum can be classified as phenolic acids, flavonoids and condensed polymeric phenols known as tannins. Phenolic acids, free or bound as esters, are concentrated in the outer layers of the grain. They inhibit growth of microorganisms and probably impart resistance against grain mould.**

**Flavonoids in sorghum, derivatives of the monomeric polyphenol flavan-4-ol, are called anthocyanidins. The two flavonoids identified to be abundant in sorghum grains are luteoforol (Bate-Smith, 1969) and apiforol (Watterson and Butler, 1983). The latter compound was also found in sorghum leaves. Jambunathan et al. ( 1986) observed that**

**resistance to grain mould rather than to birds (Subramanian et al., 1983) was associated with flavan-4-ol content of the grain. Though low-molecular-weight flavonoids from other plant sources were found to be antinutritional in rats ( Mehansho, Butler and Carlson, 1987 ),so far there has been no evidence that sorghum flavonoids have similar properties.**

**Tannins are polymers resulting from condensation of flavan-3-ols. Gupta and Haslam (1980) referred to sorghum tannins as procyanidins because they thought that cyanidin was usually the sole anthocyanidin involved. During grain development, flavonoid monomers are synthesized and then condense to form oligomeric proanthocyanidins of four to six units.**

**Some varieties of sorghum containing high tannin in the grain were found to be bird resistant (Burns,1971; Tipton et al., 1970). Tannins are the most abundant phenolic compound in brown bird-resistant sorghum. During maturation the brown-sorghum grain develops astringence which imparts resistance against bird and grain mould attack. This quality is important in arid and semi-arid regions where other crops fail. In some of these regions, annual losses in grain production as high as 75 percent or sometimes more have been reported (McMillan et al., 1972; Tipton et al., 1970).**

**Tannins, while conferring the agronomic advantage of bird resistance, adversely affect the grain's nutritional quality (Salunkhe et al., 1982; Salunkhe, Chavan and Kadam, 1990; Butler et al., 1984, 1986). Growth retardation was observed in chicks fed high-tannin**

**sorghums. Tannins in the grain impart an astringent taste which affects palatability, reducing food intake and consequently body growth (Butler et al., 1984). Tannins bind to both exogenous and endogenous proteins including enzymes of the digestive tract, affecting the utilization of proteins (Asquith and Butler 1986; Griffiths, 1985; Eggum and Christensen, 1975). Several studies in rats, chicks and livestock have shown that high tannin in the diet adversely affects digestibility of protein and carbohydrates and reduces growth, feeding efficiency, metabolizable energy and bioavailability of amino acids (Rostango, 1972). Some of the antinutritional effects of high-tannin sorghum may be due to associated lowmolecular-weight flavonoids which are readily absorbed, inhibiting the metabolic utilization of digested and absorbed foodstuffs (Butler, 1988; Mehansho, Butler and Carlson, 1987).**

**There is no direct evidence regarding antinutritional effects of dietary tannins in human subjects, although high dietary tannin may have some carcinogenic effect (Morton, 1970; Singleton and Kratzer, 1973). Iron absorption in Indian women was lower when they were fed porridge prepared from bird-resistant high-tannin sorghum in place of porridge prepared from tannin-negative sorghum (Gillooly et al., 1984). On the other hand, studies in normal and anaemic subjects (Radhakrishnan and Sivaprasad, 1980) have shown that availability of iron was affected more by physic acid than by the tannin content of the grain. The tannin content of the socalled high-tannin sorghum used by these workers was only 160 mg catechin equivalents per 100 g, and this was much lower than that normally found in birdresistant sorghum varieties.**

**Considerable efforts have been made to develop methods to improve the nutritional quality of bird-resistant sorghum (Salunkhe, Chavan and Kadam, 1990). Tannins and associated polyphenols are concentrated in the testa or seedcoat and can be removed by milling. However milling by traditional (mortar and pestle) as well as mechanical methods was shown to result in considerable losses in nutrients, and the flour produced was poor in yield as well as in nutritional quality (Chibber, Mertz and Axtell, 1978). Mwasaru, Reichert and Mukuru ( 1988) have suggested that for milling to be commercially economical, varieties of sorghum with round grains and hard endosperm and containing just adequate tannin for bird resistance and other agronomically desirable properties should be developed. They have identified such varieties giving flour extraction levels of 70 percent or higher on abrasive dehulling (Reichert, Mwasaru and Mukuru, 1988).**

**Price, Hagerman and Butler (1980) observed that the tannin content of sorghum flour decreased when it was mixed into batter, and there was further reduction on cooking. However, the growth of rats fed cooked or uncooked batter was lower than that of animals fed raw flour. Germination was also found to decrease tannin content in sorghum (Osuntogun et al., 1989) and finger millet (Udayasekhara Rao and Deosthale, 1988). However, the tannin content of the germinated sorghum rose again significantly upon drying.**

**Different methods have been tried to inactivate or detoxify the tannins in birdresistant sorghums to improve their nutritional quality (Salunkhe, Chavan and Kadam, 1990).**

**Moisturizing the grains with alkali several hours prior to utilization, including treatment of whole grain with dilute aqueous ammonia, was found to be quite effective (Price and Butler, 1979). In traditional processing of high-tannin sorghums, prior treatment of the grain with alkalis is an important step. In making sorghum beer, the grains are soaked overnight with moistened wood ash; the alkalis released from the ash were found to inactivate the tannins (Butler, 1988). This observation is very important, since the product before fermentation is used for feeding children in certain parts of eastern Africa. Muindi and Thomke (1981) found that treatment of high-tannin sorghum with Mugadi soda solution was also effective in detoxification of tannins. Other methods suggested to improve the nutritional quality of bird-resistant sorghum include treatment with formaldehyde (Daiber and Taylor, 1982) and polyethylene glycol (Hewitt and Ford, 1982), gelatin (Butler et al., 1986) and high-moisture reconstitution (Teeter e! al., 1986). Supplementation of high-tannin diets with orthophosphoric acid or dicalcium phosphate (Ibrahim et al., 1988) or sodium bicarbonate (BandaNyirenda and Vohra, 1990) also had a positive effect in terms of detoxification of tannins.**

**Among millets, finger millet was reported to contain high amounts of tannins (Ramachandra, Virupaksha and Shadaksharaswamy, 1977), ranging from 0.04 to 3.47 percent (catachin equivalents). In vitro protein digestibility was negatively associated with the tannin content of finger millet varieties. In studies reported by Udayasekhara Rao and Deosthale (1988), white varieties of finger millet had no detectable tannin, while the tannin content of brown varieties ranged from 351 to 2 392 mg per 100 g. After extraction**

of tannin the ionizable iron in brown finger millet varieties rose by 85 percent, and addition of the extracted tannin to white varieties reduced the ionizable iron by 52 to 65 percent. These studies indicated that the poor iron availability (represented by low ionizable iron) in brown varieties is due to their high tannin content.

In the fermented pearl millet product rabadi, polyphenols decreased by 10 to 12 percent after nine hours of fermentation (Dhankher and Chauhan, 1987).

## Digestive enzyme inhibitors

Inhibitors of amylases and proteases have been identified in sorghum and some millets (Pattabiraman, 1985). Chandrasekher, Raju and Pattabiraman (1981) screened millet varieties for inhibitory activity against human salivary amylase. Japanese barnyard, common, kodo and little millet strains had no detectable activity. One pearl millet and two sorghum strains did not show any inhibitory activity against a-amylase, while other strains of sorghum and pearl, foxtail and finger millets showed appreciable activity, indicating it to be a varietal and species character. Sorghum had the highest inhibitory activity against human, bovine and porcine amylases; foxtail millet did not inhibit human pancreatic amylase, while extracts from pearl and finger millets inhibited all a-amylases tested. The inhibitors were non-dialysable and were inactivated by pepsin treatment. Inhibitors from sorghum and foxtai millets were more thermolabile than those from finger

**and pearl millets.**

**Similar screening for protease inhibitors (Chandrasekher, Raju and Pattabiraman, 1982) showed that kodo, common and little millet varieties had no pro/ease-inhibitory properties while pearl, foxtail and barnyard millets displayed only antitrypsin activity. Finger millet extracts were found to have the highest activity against bovine trypsin (33.3 units) and chymotrypsin (12.5 units), as well as against porcine elastase (Pattabiraman, 1985). Extracts from sorghum and pearl, foxtail and barnyard millets inhibited the proteolytic enzymes of both human and bovine pancreatic preparations.**

**Manjunath, Veerbhadrappa and Virupaksha (1981) purified and characterized trypsin inhibitors from finger millet and found the final preparation homogeneous by sodium dodecyl sulphate polyacrylamide gel electrophoresis (SDS-PAGE) at pH 4.3 and ultracentrifugation. The purified antitrypsin inhibitor was found to be stable over a wide range of temperature and pH (3 to 12). While it was active against bovine trypsin, it did not inhibit bovine a-chymotrypsin, pepsin, papain or subtilisin. It was found to have inhibitory properties against salivary and pancreatic amylases. Almost simultaneously, Shivara; and Pattabiraman (1981) independently reported that a single bifunctional protein factor in finger millet had inhibitory activity against trypsin and amylase with two separate active sites.**

**Chandrasekher and Pattabiraman ( 1982) purified and characterized two trypsin inhibitors**

**from pearl millet. Both were active against bovine trypsin but inactive against bovine a-chymotrypsin. Fairly stable to heat, the two inhibitors were also stable under a wide pH range, from 1 to 9.**

**The nutritional significance of the enzyme inhibitors present in sorghum and millets is not clearly understood: more research on enzyme inhibitors of cereal grains is needed.**

## Goitrogens

**Iodine is an essential micronutrient for all animal species, and iodine deficiency is among the most widely prevalent nutritional problems in many developing countries (DeMaeyer, Lowenstein and Thilly, 1979). Though environmental iodine deficiency is a prerequisite to goitre formation, the incidence of goitre in animals and humans with normal dietary intake of iodine suggests there are other factors in the aetiology of simple goitre. The observation that cabbage feeding produced thyroid hyperplasia in rabbits was the first milestone of progress in this field. A large number of foodstuffs possess antithyroid agents, collectively designated as goitrogens. The isolation and identification of l-5-vinyl-2-thiooxazolidone, a goitrogen of some foods in the Cruciferae family (Astwood, Greer and Ettlinger, 1949), led to the search for similar agents in more commonly eaten foodstuffs. Cyanogenic glycoside, which can be hydrolysed to highly potent antithyroid thiocyanates, was found to be present in cassava tubers, a staple of tropical Africa, and was implicated**

in the high incidence of goitre in cassava-eating populations.

Another staple food implicated in the aetiology of goitre is pearl millet. In the Sudan, Osman and Fatah ( 1981 ) observed that in rural Darfur Province, where pearl millet was the only staple, the incidence of goitre was higher than in urban regions where other foodgrains such as sorghum were consumed. Consumption of pearl millet is considered one of the factors responsible for the high incidence of goitre in rural populations. A positive correlation observed between the incidence of goitre and per caput production of pearl millet in six African countries (Klopfenstein, Hoseney and Leipold, 1983a) supports this viewpoint. Furthermore, Osman and Fatah (1981) observed that rats fed pearl millet diets developed abnormal thyroidhormone patterns with hyperplasia while animals fed sorghum were unaffected. A thioamide-type goitrogen was suspected to be present in the pearl millet grown and consumed in the region. Sudanese girls with goitre had relatively high serum isothiocyanate which was attributed to their consumption of pearl millet (Osman, Basu and Dickerson, 1983).

Feeding trials in rats showed that the goitrogen inhibited deiodination of thyroxine (T4) to triiodothyronine (T3), the metabolically more active form of the hormone. Iodine supplementation did not alleviate the goitrogenic effect of pearl millet.

Studies reported by Klopfenstein, Hoseney and Leipold (1983b) showed that the goitrogenic principle in pearl millet was present in both the bran and endosperm portions

**of the grain and was not destroyed by grain fermentation. The observation that autoclaving of the millet reduced its goitrogenic properties suggested a volatile or heat-labile nature of the active principle. Birzer, Klopfenstein and Leipold ( 1987) found that the goitrogenic principle of pearl millet was alcohol extractable and probably present as the c-glucosyl flavones vitexin, glucosyl vitexin and glucosyl orientin. The alcohol extract of wetted and dried pearl millet grain was found to be more goitrogenic; it contained no vitexin nor its glycosides but showed the presence of the phenolic compounds phloroglucinol, resorcinol and p-hydroxybenzoic acid, which are known for their antithyroid properties. Antithyroid activity was reported to be higher in extracts prepared from boiled or stored pearl millet (Gaitan et al., 1989).**

**Tempering the grain to 26 percent moisture overnight prior to milling resulted in a flour with no goitrogenic activity (Klopfenstein, Leipold and Cecil, 1991). A strong positive correlation was observed between c-glycosyl flavone level and the thyroid histopathology and hormone pattern. Yellowcoloured pearl millet was less goitrogenic than brown or grey millet. More evidence is needed however, to understand the mechanism of the antithyroid action of the flavonoids in pearl millet (Birzer and Klopfenstein 1988).**

## Amino acid imbalance and pellagra

**Dietary deficiency of niacin, a B-complex vitamin, is well accepted as a causative factor of**

the nutritional disorder known as pellagra in humans. The classical clinical manifestations of pellagra are bilateral and symmetrical photosensitive dermatitis, diarrhoea and dementia or impairment of the mental function. Endemic pellagra in sorghum-eating populations was first described by Gopalan and Srikantia ( 1960), particularly in poor agricultural labourers around Hyderabad in Andhra Pradesh. About I percent of the hospital admissions were pellagrins and about 10 percent of the mental hospital cases showed clinical features of the disease (Gopalan and Vijayaraghavan, 1969).

Traditionally, pellagra has been associated with consumption of maize. It is rarely observed in populations subsisting on other cereals or millets. The pellagragenic properties of maize are largely explained by the poor niacin bigavailability and low tryptophan content of its protein. On the other hand, niacin in sorghum is biologically available (Belavady and Gopalan, 1966) and the tryptophan content of sorghum protein is not low. These observations suggest that the aetiology of pellagra in sorghum eaters might be different. A common feature of sorghum and maize is that the proteins of both these grains contain a relatively high proportion of leucine. It was therefore suggested that an amino acid imbalance from excess leucine might be a factor in the development of pellagra.

Clinical, biochemical and pathological observations in experiments conducted in humans as well as laboratory animals have shown that high leucine in the diet impairs the metabolism of tryptophan and niacin and is responsible for the niacin deficiency in

**sorghum eaters (Belavady, Srikantia and Gopalan, 1963; Srikantia et al., 1968; Ghafoorunissa and Narasinga Rao, 1973). High leucine is also a factor contributing to the pellagragenic properties of maize, as shown by studies in which dogs fed the low-leucine maize variety Opaque-2 did not suffer from niacin deficiency while those fed high-leucine Deccan hybrid maize showed typical features of the canine form of pellagra (Belavady and Gopalan, 1969). All these observations support the hypothesis that excess leucine in sorghum is aeliologically related to pellagra in sorghumeating populations.**

**Further studies have shown that the biochemical and clinical manifestations of dietary excess of leucine could be counteracted not only by increasing the intake of niacin or tryptophan but also by supplementation with isoleucine (Belavady and Udayasekhara Rao, 1979; Krishnaswamy and Gopalan, 1971). These studies suggested that the leucine/isoleucine balance is more important than dietary excess of leucine alone in regulating the metabolism of tryptophan and niacin and hence the disease process.**

**Pellagra is not endemic in all the areas where sorghum is the main staple. This probably suggests that factors other than excess leucine and poor leucine/isoleucine balance in sorghum proteins are responsible for the development of the disease. Recent investigations have shown that vitamin B6 is involved in the metabolism of leucine as well as that of tryptophan and niacin, and it is therefore suggested that regional differences in the prevalence of pellagra might be related to the nutritional status of the population in terms of vitamin B6 (Krishnaswamy et al., 1976).**

**Hulse, Laing and Pearson (1980), after reviewing the literature available to them, expressed the view that experimental evidence is lacking from other laboratories to support the hypothesis regarding the excess leucine in sorghum as an aetiological factor leading to niacin deficiency. Studies in human subjects (Nakagawa et al., 1975) as well as in rats (Nakagawa and Sasaki, 1977) did not show any effect of excess dietary leucine on tryptophan and niacin metabolism. Similarly, Cook and Carpenter (1987) failed to observe any aberration in niacin metabolism indicative of niacin deficiency resulting from excess leucine in chicks, rats and dogs. In view of these diverse observations, additional research is required to resolve this issue.**

**Qualitative improvement in the diet as a whole would be the right approach for prevention and control of any nutritional disorder in the population. However, such a blanket solution is not practicable considering economic and socio-cultural constraints. Based on the understanding of the factors that lead to pellagra in sorghum eaters, one of the alternative approaches to combating the disease would be identification of sorghum varieties with low leucine content and hence better leucine/isoleucine balance in the protein. Screening of sorghum varieties from a worldwide sorghum germplasm collection showed that genetic variability in protein content and Iysine and leucine content of the protein is very large (Deosthale, Nagarajan and Visweswar Rao, 1972). Four varieties of sorghum (IS 182, IS 199, IS516 and IS4642) were identified as having a stable low-leucine character (leucine content below 11 g percent in the protein). Experiments in dogs have shown that animals fed sorghum proteins with less than 11 g percent leucine did not**

**suffer from nicotinic acid deficiency (Belavady and Udayasekhara Rao, 1979). The four selected varieties are therefore considered safe and could be beneficially exploited to prevent pellagra in endemic areas (Deosthale, 1980).**

**Two Ethiopian sorghum varieties were identified for their high protein and high lysine content (Singh and Axtell, 1973a). Analysis of grain samples of those varieties when grown in India not only confirmed their high-protein, highlysine character but also showed that their niacin content was about two to three times higher than that of normal sorghum grains (Pant, 1975). This observation indicates the second alternative approach to increasing the niacin content of the diet. Consumption of such varieties of sorghum may be expected to control and prevent pellagra even if the leucine/isoleucine balance is unfavourable.**

## Fluorosis, urolithiasis and other trace-element effects

**High fluoride content of drinking-water is the most important factor in the aetiology of endemic fluorosis, but it is believed that diet and nutritional status is one of the factors that can influence the course of the disease (Pandit et al., 1940; Siddiqui, 1955). In certain parts of India where fluorosis is endemic, the agroclimatic conditions are conducive for the cultivation of sorghum and millets and these foodgrains are the main staple in the diets of the population. In fluorotic areas of Andhra Pradesh, a clinical manifestation of bone**

**deformation known as genu valgum was seen more frequently in subjects whose staple was sorghum (Krishnamachari and Krishnaswamy, 1974). Furthermore, it was observed that retention of fluoride was significantly higher on a sorghum diet than on rice (Lakshmaiah and Srikantia, 1977).**

**Several factors including trace-element nutrition have been implicated in the aetio-pathology of fluorosis and genu valgum. In this respect an observation of importance is that grain samples of sorghum and pearl millet grown in a fluorosis area had 60 percent more molybdenum than those from a nonfluorosis area (Deosthale, Krishnamachari and Belavady, 1977). Experiments in human subjects have shown that high intake of molybdenum affects copper metabolism (Deosthale and Gopalan, 1974). Moreover, in areas where the incidence of genu valgum was high, the copper content of water was found to be very low as compared to that in non-genu valgum areas (Krishnamachari, 1976); this perhaps indicates differences in the copper nutritional status of the populations in these areas. Both copper and fluoride have a role in bone formation, and molybdenum promotes fluoride absorption (Underwood, 1971). However, no clear-cut evidence is available to explain the mechanism of this interrelationship with regard to the progression of the disease.**

**Urolithiasis, which is also endemic in certain parts of India, is a condition in which stones or calculi are formed in the urinary tract. This stone formation is said to be common in millet-eating populations (Patwardhan, 1961a). Several promoters and inhibitors of the**

**lithogenic process have been implicated. There is some evidence to suggest that some trace elements are involved in the genesis of urinary calculi (Eusebio and Elliot, 1967; Satyanarayana et al., 1988). Molybdenum, which is found in greater amounts in sorghum than in other foods, is an integral part of the xanthine oxidase system and is involved as such in the synthesis of uric acid, a component of urinary calculi. In studies conducted in human volunteers, however, dietary intake of molybdenum had no significant effect on uric acid excretion (Deosthale and Gopalan, 1974). Several trace elements have been identified in appreciable amounts in urinary calculi and kidney stones. The significance of their presence in relation to lithogenesis needs investigation.**

**O'Neill et al. ( 1982) observed that in parts of China, foxtail-millet bran contained very high amounts of silicon, up to 20 percent. High silicon from the soil accumulates in the bristles and is deposited in the grain pericarp. Consumption of this high-silicon foxtail millet has a role in the aetiology of oesophageal cancer in northern China.**

## Mycotoxins

**Like other cereals, sorghum and millets are susceptible to fungal growth and mycotoxin production under certain environmental conditions. Mycotoxins not only threaten consumer health but also affect food quality, causing huge economic losses. To help developing countries improve their mycotoxin prevention and monitoring programmes**

**FAO has published a manual on training in mycotoxin analysis (FAO, 1990a).**

**Storage fungi, mostly of the genera Aspergillus and Penicillium, are found on foodgrain stored with moisture content greater than 13 percent (Sauer, 1988). Mouldy sorghum earheads were shown to be contaminated with aflatoxins B and G in India (Tripathi, 1973), in Uganda (Alpert et al., 1971) and in the United States (Shotwell et al., 1969). Aflatoxin has been shown to be hepatotoxic, carcinogenic, mutagenic and teratogenic. Proper drying and storage would greatly prevent the contamination of foodgrains. In India, infestation of pearl millet by a parasitic fungus, Claviceps purpurea, has caused an outbreak of ergotism, which is characterized by symptoms of nausea, vomiting, giddiness and somnolence (Patel, Boman and Dalal, 1958; Krishnamachari and Bhat, 1976).**

**A mouldy-grain toxicosis associated with consumption of sorghum grain was reported from Japan, and the causative fungus was Fusarium sp. (Saito and Ohtsubo, 1974). A strain of Fusarium incarnatum was isolated from naturally infested mouldy sorghum. The toxic metabolite present on mouldy sorghum grain infected with an isolated Fusurium strain was characterized for its chemical and biological properties. It was found to be T2 toxin, 3a-hydroxy4,15-diacetoxy-8a-(3-methylbutyryloxy)- 12,13 epoxy trichothecene.**

**Fusarium spp., primarily from infected millets, have been implicated in the aetiology of alimentary aleukia in humans in the former Soviet Union (Joffe, 1965).**

## Infestation

**Insect damage during storage not only results in the loss of foodgrain but also affects its nutritional quality. Kapu, Balarabe and Udomah (1989) reported that crude protein values of all the foodstuffs including sorghum decreased significantly with insect damage. Pant and Susheela (1977) observed varietal differences in susceptibility to insect attack in 10 months' storage under ambient temperature and humidity. Moderate insect infestation did not alter the protein quality of the grain, but high infestation (30 percent) decreased it significantly. Insect-infested grain showed significant losses in total fat, mineral matter, thiamine and riboflavin. Sood and Kapoor (1992) have observed reduction in protein and starch digestibility on grain infestation in sorghum, wheat and maize. This effect was found to be dependent on the distribution of protein and starch in the kernel component**

**as well as on the feeding preferences of the insect. Infestation by the lesser grain borer, Rhizopertha dominica an insect which feeds on endosperm, was found to reduce starch digestibility, while that by the khapra beetle, Trogoderma granarium, which attacks the germ, reduced the protein digestibility.**

## Conclusion

**Several factors as discussed above affect the nutritional quality of sorghum and millets.**

**Fortunately there are methods available to eliminate, inactivate or prevent the antinutritional and/or toxic principles that may be present naturally or because of contamination. Grain processing, discussed in Chapter 3, has a significant role.**

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# Annex - Some recipes based on sorghum and millets

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**UJI**
**Thin porridge**

***Method***

1. **Mix the flour with about 1/2 cup water.**
2. **Place in a covered container and allow to ferment 24 to 48 hours in a warm place. Omit this step for an unfermented product.**

3. **Boil remaining water and add fermented flour to it.**
4. **Cook for 10 to 15 minutes until smooth and thick.**
5. **Add sour milk (or water or banana juice), stir and boil for another 2 minutes.**
6. **Add sugar and serve hot at breakfast or lunch. Serves 2-3.**

***Notes***

**A light colour, smooth, flowing, creamy consistency and bland to sour taste and aroma are preferred. A dark, lumpy, grainy product with off flavour is not desired.**

**Kenya**
**United Republic of Tanzania**
**Uganda**

***Ingredients***

**1 cup sorghum or millet flour**
**3-4 cups water**
**1 cup sour milk, water or banana juice**
**2 tablespoons sugar, or salt or lemon juice to taste**

**OGI**

**Thin porridge**

***Method***

1. **Soak dehulled grains in cold water for 18 to 48 hours to soften and ferment the grains.**
2. **Wash the grains and ground to a coarse paste using a grinding stone.**
3. **Screen the slurry through muslin cloth and discard the bran and coarse particles remaining on the cloth.**
4. **Let the strained slurry stand for 5 to 6 hours and pour off the excess water, leaving just enough to cover the settled paste.**
5. **Bring water to boil.**
6. **Pour the paste in the boiling water (2 tablespoons for every 6 cups water) and stir vigorously until the paste gelatinizes.**
7. **Cover the bowl and cook for another 2 to 3 minutes.**
8. **Serve the thin, hot porridge as it is or add sugar or salt to taste.**

***Notes***

**The product should be light in colour, either white or creamy. Traditionally ogi is not stored. *Kafer, eko or ogide*, thicker versions of ogi, are stored. Change in flavour, texture or aroma is unacceptable.**

**Nigeria**

*Ingredients*

Dehulled sorghum grains
Water
Sugar or salt to taste

**ALKALI T**
**Stiff porridge**

*Method*

1. Boil about 4 litres water in a metal pot.
2. Mix 10 9 wood ash in 650 ml water.
3. Add about 500 9 sorghum flour and stir to form a homogeneous paste.
4. Swirl the paste in the boiling water.
5. Stir the boiling mixture about 8 minutes. (Sometimes this mixture is consumed as thin porridge.)
6. Reduce the heat under the pot. Take out approximately one-third of the mixture and set it aside in a separate bowl.
7. Keep the mixture in the pot boiling and add, in small lots, the remaining sorghum

**flour.**

8. **After each addition beat the mixture vigorously with a flat wooden spoon. When the paste thickens too much to beat, add some of the thinner porridge that was kept aside. Again add flour and beat. Continue this cycle until all the flour and set-aside porridge are mixed in the boiling pot to form a homogeneous, thick paste.**
9. **Reduce heat, cover the pot and allow the paste to cook over low heat for about 12 minutes.**
10. **Remove the to from the fire, cool for about an hour and serve.**

**Mali**

***Ingredients***

**1.25 kg dehulled sorghum flour passed through 1 mm mesh**
**10 G wood ash extract**

**TUWO**
**Stiff porridge**

***Method***

1. **Bring water to boil.**

2. **Prepare a paste of the flour in cold water.**
3. **Add the paste in small amounts to the boiling water and stir vigorously to prevent lump formation. For acid tuwo preparation cook the paste in water containing either lemon juice or tamarind pulp extract.**
4. **Cool the thick porridge.**
5. **Serve with vegetable sauce.**

***Notes***

**A product prepared from dehulled grains is normally preferred. Whole-grain tuwo is tough, non-elastic and dark in colour.**

**Nigeria**

***Ingredients***

**4 cups flour of whole or dehulled sorghum or millet**
**9 cups water Lemon juice or tamarind pulp extract (optional)**

**BOGOBE**
**Stiff porridge**

***Method***

1. **For fermented bogobe (motogo-wa-ting or sing), mix starter with dry sorghum meal.**
2. **Add 250 to 300 ml lukewarm water and stir to make a slurry.**
3. **Cover and allow to ferment for 24 hours.**
4. **Boil 1 500 ml water.**
5. **Add fermented meal to the boiling water. Stir frequently.**
6. **Cook for 12 to 15 minutes.**

**Non-fermented bogobe (*mosokwana*)**

1. **Boil about 1 litre water.**
2. **Add about 250 9 sorghum meal to boiling water, stirring frequently.**
3. **Cook for 20 to 30 minutes.**

***Notes***

***Motogo-wa-ting* is normally consumed with meat and vegetables in the morning and evening. *Mosokwana* is generally eaten at lunch with meat and vegetables. Bogobe with medium to coarse texture is preferred. Dark colour of the product resulting from grain pigments is not acceptable.**

**Botswana**

***Ingredients***

**300 g coarsely ground dehulled sorghum meal**
**30 g starter (sorghum meal fermented in water for 48 hours)**
**1 500 to 1 800 ml water**

**UGALI**
**Stiff porridge**

***Method***

1. **Bring water to boil (in a clay pot).**
2. **Sprinkle a small amount of flour on the surface of the water. Continue heating.**
3. **As soon as water begins to boil again, add remaining flour in small amounts. Stir constantly to avoid lump formation.**
4. **Allow to cook for 2 minutes and remove about half of the hot slurry to another container.**
5. **Vigorously mix the remaining slurry in the pot using a wooden stick with a flattened cylindrical handle.**
6. **Add the set-aside slurry and continue boiling until the right consistency is obtained.**
7. **Continue cooking on a reduced fire for about 4 to 5 minutes.**
8. **Remove the ugali to a basket made for this purpose. The whole process of ugali**

preparation takes 15 to 20 minutes.

9. Serve with meat or vegetable sauce or stew, or green vegetables. Serves 2-3.

*Notes*

Ugali should be light in colour. It should not be sticky when eaten and should maintain the same characteristics in storage for 24 hours.

Kenya
United Republic of Tanzania
Uganda

*Ingredients*

2-3 cups sorghum or millet flour
4-5 cups water

AMBALI
Stiff porridge

*Method*

1. Bring water to boil.

2. Mix the flour in cold water.
3. Add to the boiling water in small amounts.
4. Stir to prevent lump formation.
5. Cook until thick.
6. Leave overnight to ferment.
7. Add water or buttermilk. Mix well and serve.

India

*Ingredients*

1 litre water
250 g sorghum or millet flour
Salt to taste
Buttermilk (optional)

SANKATI
Stiff porridge

*Method*

1. Sieve the flour through a 20-mesh sieve and separate grits from fine flour.

2. **Boil water in a vessel.**
3. **Add grits to the boiling water while stirring.**
4. **Continue boiling and after 10 minutes gradually add the fine flour.**
5. **Continue stirring and cooking for another few minutes.**
6. **Pour the sankati on to a moist plate and prepare balls of approximately 10 cm diameter by hand.**
7. **Serve fresh with sauce, dhal, pickles, chutneys, buttermilk, curd, vegetable curries, etc. according to taste.**

***Notes***

**Sankati should be light in colour and slightly sweet in taste. It should not be sticky or pasty and should remain firm when stored in water.**

**India**

***Ingredients***

**Coarsely ground whole-grain sorghum flour, winnowed and free of bran**
**Water**

**Roti**

**Unleavened thin flat bread**

***Method***

1. **Mix flour, water and salt to form a firm dough. Knead it thoroughly.**
2. **Shape it into a ball.**
3. **Sprinkle some dry flour on a wooden board and place the dough ball on it. Flatten the dough by hand, pressing into a circle of fairly even thickness.**
4. **Bake the flat dough on a hot shallow pan or grill. After about half a minute, sprinkle water on the baking dough.**
5. **Turn the rob over and bake it on the other side for 30 seconds or until it puffs.**
6. **Serve it with pickles, chutneys, dhal or vegetable sauces.**

***Notes***

**A thin, soft, light-coloured roti is preferred. For up to 24 hours of storage it should remain soft. A dark product is not desired.**

**India**

***Ingredients***

**Whole-grain sorghum or pearl millet flour**

**Water**
**Salt to taste**
**Oil (optional)**

**TORTILLAS**
**Unfermented bread**

***Method***

1. **Prepare mesa by mixing lime solution and sorghum grain in 3:1 proportion and cooking for 3 to 10 minutes at the boiling point.**
2. **Steep for at least 4 hours.**
3. **Prepare balls from the mesa and press them into circles of about 15 cm diameter and 0.5 cm thickness.**
4. **Cook the tortillas on a grill or a traditional clay comale.**
5. **During cooking turn the tortilla once to brown it lightly on both sides.**
6. **Leave the cooked tortillas on the floor to cool a little, then keep them in a container lined with a cloth to cover.**

***Notes***

**Sorghum tortillas are off coloured compared to those made with white maize. A tortilla**

**prepared from a 1:1 mix of sorghum and maize is well accepted.**

**Central America**
**Mexico**

***Ingredients***

**Sorghum grain**
**0.5 percent lime solution**

**INJERA**
**Leavened round flat bread**

***Method***

1. **To prepare dough for 31 injera of 390 9 each, sieve 4.5 kg sorghum flour into a large bowl.**
2. **Add 1 litre water and knead well by hand.**
3. **Stir in the ersho (starter).**
4. **Add more water and knead well.**
5. **Transfer the dough into a previously used buhaka (dough container). Cover and let stand for 48 hours.**

6. **Sift 1.6 kg flour into a large bowl to prepare a batter.**
7. **Heat 1.7 litres of water to boiling.**
8. **Pour the boiling water over the flour and mix well with a wooden spoon.**
9. **Let the mixed batter stand until it cools to approximately 55C.**
10. **Add the batter to the fermented dough in the buhaka.**
11. **Add 2 litres water and mix well.**
12. **Let stand for about an hour until air bubbles form.**
13. **Heat a clay griddle (meted) over a fire half an hour before baking.**
14. **Grease the metad by sprinkling ground rapeseed over it and polishing with a folded piece of clean cloth. Dust away all the rapeseed. Grease in this way before baking each injera.**
15. **Pour the batter on to the hot greased meted using a circular motion from outside towards the centre to make a circular injera. Use about 0.5 litre of batter for each injera.**
16. **When holes begin to form on the top of the injera, cover with the griddle lid (akenbala) and bake for 2 to 3 minutes.**

***Regional variations***

**Mixing cooked dough (*absit)* with fermented dough:**

1. **Ladle out about 800 9 of the fermented dough.**

2. **Add 350 ml water and mix well.**
3. **Boil 750 ml water and stir in the above dough and water mixture.**
4. **Cook, stirring constantly, for 10 minutes.**
5. **Remove from heat. Cool to about 46C.**
6. **Add the cooked dough to the fermented dough in the *buhaka*.**
7. **Mix well with a clean stick or a clean hand.**
8. **Add 2 litres water and mix well.**
9. **Let stand for about an hour to allow the batter to rise.**
10. **Bake as described before.**

**Fermenting together a mixture of three parts uncooked and one part previously cooked dough:**

1. **A few hours after the initial dough is mixed, take out one-fourth of the dough and cook it until it reaches the consistency of a porridge.**
2. **Mix the cooked dough thoroughly into the remaining initial dough.**
3. **Leave it overnight in the dough container.**
4. **Thin the dough with warm water and bake.**

***Notes***

**Injera is consumed with wot, a stew made from meat, pulse, vegetables or their**

**combinations. Milk and milk products can also be served with injera. Desirable parameters include uniformly distributed "eyes" or perforations and a slightly sour flavour. A soft, thin, slightly moist and flexible product is accepted.**

**Ethiopia**

***Ingredients***

**6.1 kg sorghum flour**
**0.5 litre ersho (starter), a fermented thin yellowish fluid saved from previously fermented dough**
**Water**

**KISRA**
**Thin pancake-type leavened bread**

***Method***

1. **In an earthenware container, mix flour, starter and enough water to form a paste.**
2. **Allow to ferment overnight, i.e. about 18 hours.**
3. **Thin dough to the consistency of a batter.**
4. **Spread about 100 ml of the batter on a hot iron plate, using a rectangular spatula (15**

**x 5 cm) to form a very thin layer.**

5. **Bake for about half a minute.**
6. **Remove and store in a container one on top of the other.**
7. **Cover with a cloth and store for use on the same or next day.**
8. **Serve with vegetables, legumes, meat stew or soup.**

***Notes***

**A soft, thin, slightly moist and flexible product is preferred, with uniformly distributed "eyes" or perforations and a slightly sour taste.**

***Ingredients***

**9 parts sorghum flour, generally white variety**
**2 parts water**
**1 part starter (yeast inoculum from a previously fermented batch of kisra batter)**

**SORGHUM OR MILLET "RICE"**

***Method***

1. **If using whole grain, soak it overnight in water and rinse it clean.**
2. **Boil or steam the dehulled or soaked whole grain until soft (20 to 40 minutes).**

3. **Serve hot with meat or vegetables.**

**India**

***Ingredients***

**1 volume dehulled or whole grain**
**3-4 volumes water**

**SORGHUM OR MILLET GRAINS WITH PULSE**

***Method***

1. **Bring water to boil.**
2. **Add pulse and boil until partially done.**
3. **Add sorghum or millet grain and continue boiling until tender.**
4. **Season as desired.**
5. **Serve hot with greens and lemon or orange slices.**

**India**

***Ingredients***

**2 cups whole or cracked grain**

**1 cup green gram dhal, peas, beans, cowpeas or other pulse**

**7 cups water**

**PATE**

**Dehulled cracked grain**

***Method***

1. **Bring water to boil.**
2. **Add bean cake, onion, tomatoes, chill) peppers, salt and pepper.**
3. **Add coarsely ground grain.**
4. **Cook for 8 to 10 minutes.**
5. **Add spinach and continue cooking for another 2 minutes.**
6. **Serve hot.**

***Notes***

**A sticky product with poorly defined grains is not desired.**

**Nigeria**

***Ingredients***

**4 cups coarsely ground whole or dehulled sorghum or millet grain**
**7 cups spinach**
**2 large chill) peppers (chopped)**
**6 medium-sized tomatoes**
**2 medium-sized locust bean cakes**
**1 onion**

**KICHIDI**

***Method***

1. **Heat oil in a pot.**
2. **Add spices.**
3. **Fry onion and garlic.**
4. **Add water and boil.**
5. **Add dehusked millet, rice, soaked chickpea dhal, groundnuts and salt.**
6. **Cover and cook until done.**
7. **Serve hot, garnished with grated coconut and green coriander leaves.**

**India**

***Ingredients***

**2 cups dehusked sorghum or millet**
**1/2 cup rice**
**1/4 cup chickpea dhal soaked in water**
**1/2 cup groundnuts soaked in water**
**2 small onions**
**6 cloves garlic**
**50 g vegetable oil**
**2 teaspoons mixed spices: mustard, cumin, asafoetida and turmeric**
**Salt to taste**

**COUSCOUS**

***Method***

1. **Wet the finely ground flour with cold water and knead it until flour particles agglomerate.**
2. **Force the mixture through a fine screen (1.5 mm mesh).**
3. **Place the grains in a perforated pot fitted over another pot containing boiling water.**
4. **Put a cloth seal at the joint between the two pots. Heat the lower pot to steam the grains above for about 15 minutes. They will form a single large chunk.**
5. **Take out the chunk, break it into small aggregates and transfer them back to steam for another 15 minutes.**

6. **Remove the chunk, break it into aggregates and sift them through a sieve (2.5 mm).**
7. **Dry and store for future use.**
8. **To prepare couscous for serving, sprinkle cool water on the aggregates.**
9. **Mix thoroughly with fingers.**
10. **Mix the grains with ground baobab leaf powder and other ingredients such as peanut paste, okra, etc. and give it a final steaming for 15 minutes.**
11. **Allow it to cool slowly**
12. **Serve with sauce or milk, or dry it and use as a convenience food.**

**West Africa**

***Ingredients***

**Finely ground sorghum or millet flour**

**FURA**
**Snack preparation**

***Method***

1. **Mix flour, water and spices.**
2. **Prepare small round balls (2 to 3 cm in diameter).**

3. **Drop them into boiling water and cook for 30 minutes.**
4. **Pound cooked balls with water and spices until a smooth, elastic and cohesive lump is formed.**
5. **Again prepare small balls, rolling between the palms of the hand or on a wooden board dusted with dry flour.**
6. **Serve as it is or with nono, yoghurt or sour milk, as a snack.**

**Nigeria**

***Ingredients***

**4 cups millet or sorghum flour (sifted)**
**2 teaspoons hot spices**
**6 cups water**
**2 cups nono (fermented milk), yoghurt or sour milk**

**POPPED SORGHUM**

***Method***

1. **Moisten the grains by sprinkling with water.**
2. **Heat the grains in a covered pan over the fire.**

3. **Serve the popped grains as a snack after sprinkling with salt and pepper.**
4. **Other serving ideas: add some sugar syrup and butter and shape into balls; or serve with milk and a little sugar.**

**India**

***Ingredients***

**Sorghum grain (popping variety)**

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# Bibliography

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**Abdelrahman, A., Hoseney, R.C. & Varriano-Marston, E. 1983. Milling process to produce low-fat grits from pearl millet. Cereal Chem. 60: 189-191.**

**Abdelrahman, A., Hoseney, R.C. & Varriano-Marston, E. 1984. The proportions and chemical compositions of hand-dissected anatomical parts of pearl millet. J. Cereal Sci. 2: 127-133.**

**Adams, C.A., Novellie, L. & Liebenberg, N.V.d.W. 1976. Biochemical properties and ultrastructure of protein bodies isolated from selected cereals. Cereal Chem., 53: 1-12.**

**Adrian, J., Murias de Queroz, M.J. & Frangne, R. 1970. La vitamine PP dans les graines de crales et de lgumineuses. Ann. Nutr. Aliment. 24: 155- 166.**

**Ahuja, V.P., Singh, J. & Naik, M.S. 1970. Aminoacid balance of proteins of maizc and sorghum. Indian .1. Genet. Plant Breed. 30: 727-731.**

**Ali, H.l. & Harland, B.F. 1991. Effects of fibre and phytate in sorghum flour in weaning rats: a pilot study. Cereal Foods World 36: 254. (Rsum)**

**Aliya, S. & Geervani, P. 1981. An assessment of the protein quality and vitamin B content of commonly used fermented products of legumes and millets. J. Sci. Food Agric.. 32: 837-842.**

**Almeida-Dominguez, H.D., Serna-Saldivar, S.O. & Rooney, L.W. 1991. Properties of new and commercial sorghum hybrids for use in alkaline-cooked foods. Cereal Chem. 68: 25-30.**

**Alpert, M.E., Hutt, S.R., Wogan, G.N. & Davidson, (C.S. 1971. Association between aflatoxin content of food and hepatoma frequency in Uganda. Cancer, 28: 253-260.**

**Aluko, R.E,. & Olugbemi, L.B. 1989. Sorghum as a raw material in the baking iindustry. Paper presented at the Symposium on the Current Status and Potential of Industrial Uses of Sorghum in Nigeria, Kano. Nigria, 4-6 dcembre.**

**Andhra Pradesh Agricultural University. 1991. Rural food enterprises for production of low cost supplementury foods using millets and legumes. Terminal report of the IDRC-funded project. Hyderabad. Inde. 135 p.**

**Asquith, T.N. & Butler,L.C.1986. Interaction of condensed tannins with selected proteins. Phytochemistry, 25: 1591-1593.**

**Astwood, E.B., Greer, M.A. & Ettlinger, M.G. 1949. /-5-Vinyl-2-thiooxazolidone, an antithyroid compound from yellow turnip and from brassica seeds. J. Biol. Chem., 181: 121-130.**

**Au, P.M. & Fields, M.L. 1981. A research note on nutritive quality of fermented sorghum. J. Food Sci., 46: 652-654.**

**Axtell, J.D., Kirleis, A.W., Hassen, M.M., D'Croz Mason, N., Mertz, E.T. & Munck, L. 1981.**

**Digestibility of sorghum proteins. Proc . Natl. Acad. Sci . USA, 78: 13331335.**

**Babu, B.V., Ramana, T. & Radhakrishnan, T.M. 1987. Chemical composition and protein content in hybrid varieties of finger millet. Indian J. Agric. Sci., 57: 520-522.**

**Bach Knudsen, K.E., Kirleis, A.W., Eggum, B.O. & Munck, L. 1988. Carbohydrate composition and nutritional quality for rats of sorghum T prepared from decorticated white and whole grain red flour. J. Nutr., 118: 588-597.**

**Bach Knudsen, K.E. & Munck, L. 1985. Dietary fibre contents and compositions of sorghum and sorghum-based foods. J. Cereal Sci., 3: 153-164.**

**Bach Knudsen, K.E., Munck, L. & Eggum, B.0.1988. Effect of cooking, pH and polyphenol level on carbohydrate composition and nutritional quality of a sorghum (Sorghum bicolor (L.) Moench) food, ugali. Br. J. Nutr., 59: 31 -47.**

**Badi, S.M., Bureng, P.L. & Monawur, L.Y. 1987. Kisra upgraded technology. Khartoum, Soudan, Food Research Centre. 15 p.**

**Badi, S.M., Bureng, P.L. & Monawar, L.Y. 1988. Commercial production: a breakthrough in kisra technology. In 4th Quadrennial Symposium on Sorghum and Millets, 8th International Cereal and Bread Congress, Suisse, 26-27 mars 1988, p. 3145. Vienne,**

**International Association for Cereal Science and Technology.**

**Bad;, S.M. & Hoseney, R.C. 1976. Use of sorghum and pearl millet flours in cockies. Cereal Chem., 53: 733-738.**

**Badi, S.M. & Hoseney, R.C. 1977. Use of pearl millet and sorghum flours in bread and cockies. In D.A.V. Dendy, d. Proceedings of a symposiumon sorghum and millets for human food Vienne, l l-12mai 1976, p. 37-39. Londres, Institut des produits tropicaux.**

**Badi, S.M., Hoseney, R.C. & Finney, P.L. 1976. Pearl millet. lI, Partial characterization of starch and use of millet flour in breadmaking. Cereal Chem., 53: 718724.**

**Badi, S.M., Perten, H. & Abert, P. 1980. New food product "Pearl Dura". Rep. Int. Assoc . Cereal Chem. 10: 1 02- 1 04.**

**Baghel, R.P.S., Netke, S.P. & Bajpai, L.D. 1985. Nutritive value of kangni. Poult. Guide 22: 28-29.**

**Bailey, A.V., Sumrell, G. & Burton, G.W. 1979. Pentosans in pearl millet. Cereal Chem., 56: 295-298.**

**Banda-Nyirenda, D.B.C. & Vohra, P. 1990. Nutritional improvement of tannincontaining sorghums (Sorghum bicolor) by sodium bicarbonate. Cereal Chem. 67: 533-537.**

**Bass, I,.N. & Stanwood, P.C. 1978. Long-term preservation of sorghum seed as aft`ected by seed moisture, temperature and atmospheric environment. Crop Sci., I8: 575-577.**

**Bassey, M.W. & Schmidt, O.G. 1989. Ahrasive-disk dehullers in Africa -from research to dissemination Ottawa, Canada, Centre de recherche pour le dveloppement international. 97 p.**

**Bate-Smith, E.C. 1969. Luteoforol (3',4,4',5,7-pentahydroxyflavan) in Sorghum vulgare L. Phytochemistry 8: 1803-1810.**

**Becker, R. & Lorenz, K. 1978. Saccharides in proso and foxtail millets. J. Food Sci., 43: 1412-1414.**

**Belavady, B. & Gopalan, C. 1966. Availability of nicotinic acid in jowar (Sorghum vulgare). Indian J. Biochem. 3: 44-47.**

**Belavady, B. & Gopalan, C. 1969. The role of leucine in the pathogenesis of canine black tongue and pellagra. Lancet, 2: 956-957.**

**Belavady, B., Srikantia, S.G. & Gopalan, C. 1963. The effect of oral administration of leucine on the metabolism of tryptophan. Biochem. J., 87: 652-655.**

**Belavady, B. & Udayasekhara Rao, P. 1979. Leucine and isoleucine content of jowar and its**

**pellagragenicity. Indian .1. Exp. Biol., 17: 659-661.**

**Beleia, A. & Varriano-Marston, E. 1981 a. Pearl millet amylases. I. Properties of partially purified alpha-amylase. Cereal Chem. 58: 433-437.**

**Beleia, A. & Varriano-Marston, E. 1981b. Pearl millet amylases. Il. Activity toward intact and heated starch granules. Cereal Chem.. 58: 437-440.**

**Beleia, A., Varriano-Marston, E. & Hoseney, R.C. 1980. Characterization of starch from pearl millets. Cereal Chem. 57: 300-303.**

**Birzer, D.M. & Klopfenstein, (C.F. 1988. The pearl millet goitrogens. Cereal Foods World. 33: 229-231.**

**Birzer, D.M., Klopfenstein, C.F. & Leipold, H.W. 1987. Goiter-causing compounds found in pearl millet. Nutr. Rep. Int.. 36: 131-140.**

**Blessin, C.W., VanEtten, (C.H. & Wiebe, R.1958. Carotenoid content of the grain from yellow endosperm-type sorghums. Cereal Chem. 35: 359-365.**

**Block, R.J. & Mitchell, M.M. 1946. The correlation of the aminoacid composition of proteins with their nutritive value. Nutr. Abstr. Rev. 16: 249-278.**

**Brookwalter, G.N., Warner, K. & Anderson, R.A. 1977. Fortification of dry milled sorghum with oilseed proteins. J. Food Sci., 42: 969-973.**

**Brown, K.H., Dickin, K.L., Bentley, M.E., Oni, G.A., Obasaju, V.T., Esrey, S.A., Mebrahtu, S., Alade, l. & Stallings, R.Y. 1988. Consumption of weaning foods from fermented cereals in Kwara State, Nigeria. In D. Alnwick, S. Moses & O.G. Schmidt, ds. Improving young childfeeding in eastern and southern Africa p. 181 - 197. Nairobi, Kenya, Centre de recherche pour le dveloppement international.**

**Bureng, P.L., Badi, S.E.N.M. & Monawar, L.Y. 1987. Hullu-murr production. Khartoum. Soudan, Food Research Centre. 10 p.**

**Burleson, C.A., Cowley, W.R. & Otey, G. 1956. Effect of nitrogen fertilization on yield and protein content of grain sorghum in the lower Rio Grande valley of Texas. Agron. J., 48:524-525.**

**Burns, R.E. 1971. Method for estimation of tannin in grain sorghum. Agron. J., 63: 511-512.**

**Butler, L.G. 1988. The role of polyphenols in the utilization of ICRISAT-mandated grain crops and applications of biotechnology for improved utilization. In Biotechnology in tropical crop improvement. Proceedings of the International Biotechnology Workshop, Patancheru, Inde, 12-15 janvier 1987, p. 147-152. Patancheru, ICRISAT.**

**Butler, L.G., Riedl, D.J ., Lebryk, D.G. & Blytt, H .J. 1984. Interaction of proteins with sorghum tannin: mechanism, specificity and signifieance. J. Am Oil Chenm. .Soc ., 6 1: 9 1 6-920.**

**Butler, L.G., Rogler, J.C., Mehansho, H. & Carlson, D.M. 1986. Dietary effects of tannins. In V. Cody & E. Middleton, ds. Plant flavonoids in biology and medicine: biochemical pharmacological and structure activity relationships. p. 141 - 157. New York, Wiley.**

**Cagampang, G.B., Grififth, J.E. & Kirleis, A.W. 1982. Modified adhesion test for measuring stickiness of sorghum porridges. Cereal Chem. 59: 234-235.**

**Cagampang, G.B. & Kirleis, A.W. 1984. Relationship of sorghum grain hardness to selected physical and chemical measurements for grain quality. Cereal Chem. 61: 100-15.**

**Canales, A.M. & Sierra,.I.A.1976. Use of sorghum. Tech. Q. Master Brew. Assoc. . Ann, 13: 114-116.**

**Carter, E.G.A. & Carpenter, K.J. 1981. Bound niacin in sorghum and its availability. Nutr. Res.. 1: 571 -579.**

**Carter, E,.G.A. & Carpenter, K.J. 1982. the available niacin values of foods for rats and their relation to analytical values. J. Nutr., 112: 2091 -2103.**

**Casey, P. & Lorenz, K. 1977. Millet - functional and nutritional properties. Baker's Dig., 51: 45-51.**

**Casier, J.P.J., de Paepe, G., Willems, H., Goffings, G. & Noppen, H. 1977. Bread from starchy tropical crops. II. Bread production from pure millet and sorghum flours, using cereal endosperm-cellwall-pentosan as a universal baking factor. In D.A.V. Dendy, d. Proceedings of a symposium on sorghum and millets for human food, Vienne, 11 - 12 mai 1976, p. 127-131. Londres, Institut des produits tropicaux.**

**Cecil, .I.E. 1986. Roller milling of sorghum and millet grain using a semi-wet process. Londres, Tropical Development Research Institute. 25 p.**

**Cecil,.l.E. 1992. Semi-wet milling of red sorghum. In M.l. Gomez, L.R. House, L.W. Rooney & D.A.V. Dendy, ds. Utilisation of sorghum and millets. p. 23-26. Patancheru, Inde, ICRISAT**

**Chandrasekher, G. & Pattabiraman, T.N.1982. Natural plant enzyme inhibitors: isolation and characterization of two trypsin inhibitors from bajra (Pennisetum typhoideum). Indian J. Biochem Biophys., 19: 1-7.**

**Chandrasekher, G., Raju, D.S. & Pattabiraman, T.N. 1981 Natural plant enzyme inhibitors a-Amylaseinhibitorsinmillets. Sci Food Agric 32 9-16**

**Chandrasekher, G., Raju, D.S. & Pattabiraman, T.N. 1982 Natural plant enzyme inhibitors Protease inhibitors in millets. J. Sci Food Agric 33: 447450**

**Chandrashekar, A. & Desikachar, H.S.R. 1986 Sorghum quality studies Part 11. Suitability for making dumpling (mudde). J. Food Sci. Technol., 23: 7- 10.**

**Chandrashekar, A. & Kirleis, A.W. 1988 Influence of protein on starch gelatinization in sorghum Cereal Chem. 65: 457-462.**

**Chauhan, B.M., Suneja, N. & Bhat, C.M. 1986. Nutritional value and fatty acid composition of some high-yielding varieties of bajra Bull Grain Technol., 24: 44-49**

**Chevassus-Agnes, S., Favier, J.C. & Joseph, A. 1976 Traditional technology and nutritive value of sorghum beer in Cameroon. Cah. Nutr. Diet. 11: 89-104**

**Chibber, B.A.K., Mertz, E.T. & Axtell, J.D. 1978. Technologie traditionnelle et valeur nutritive des bires de sorgho du Cameroun [Effects of dehulling on tannin content protein distribution and quality of high and low tannin sorghum J. Agric Food Chem., 26: 679-683**

**Chitsika, J.M. & Mudimbu, M.W. 1992. Quality criteria for opaque beer in Zimbabwe In M.l. Gomez, L R. House, L W. Rooney & D.A V. Dendy, ds. Utilizution of sorghum and millets p. 151 - 155 Patancheru, Inde ICRISAT**

**Choto, C.E., Morrad, M.M. & Rooney, L.W. 1985 The quality of tortillas containing whole sorghum and pearled sorghum alone and blended with yellow maize Cereal Chem.. 62: 51-55**

**Chung, O.K. & Pomeranz, Y. 1985 Amino acids in cereal proteins and protein fractions. In J.W Finley & D.T Hopkins, ds Digestibility and amino acid avaiability in cereals and oilseeds p. 65- 107 St Paul, Minnesota, Etats-Unis, American Association of Cereal Chemists.**

**Commission conomique pour l'Afrique.1985 Technical compendium on composite flours. Addis-Abeba Ethiopie 109p.**

**Cook, N.E. & Carpenter, K.J. 1987 Leucine excess and niacin status in rats J. Nutr. 117: 519-526.**

**Cornu, A. & Delpeuch, F. 1981 Effect of fibre in sorghum on nitrogen digestibility Am J. Clin. Nutr. 34: 2454-2459**

**Crabtree, J. & Dendy, D.A.V. 1979. Comilling of four species of millet with wheat to produce composite flours. Cereal Foods World, 24: 103- 107.**

**Dada, I,O. & Dendy, D.A.V. 1988. Cyanide content of germinated cereals and influence of processing techniques. In D. Alnwick, S. Moses & O.G. Schmidt, ds. Improving young child**

**feeding in eastern and southern Africa p. 359-365. Nairobi, Kenya, Centre de recherche pour le dveloppement international.**

**Daiber, K.H. & Taylor J.R.N. 1982. Effects of formaldehyde on protein extraction and quality of high- and low-tannin sorghum. J. Agric . Food Chem. 30: 70-72.**

**Daniel, V.A., Leela, R., Doraiswamy, T.R., Rajalakshmi, D., Venkat Rao, S., Swaminathan, M. & Parpia, H.A.B. 1965. The effect of supplementing a poor Indian ragi diet with L-lysine and DL-threonine on the digestibility coefficient, biological value and net utilization of the protein and on nitrogen retention in children. J. Nutr Diet. 2: 138-143.**

**Dassenko, S. 1980. Effect of milling, fermentation and cooking on nutritive value of pearl millet (Pennisetum americanum (L. ) Leeke). Thse de doctorat. Kansas State University, Manhattan, Kansas, Etats-Unis.**

**Davis, A.B. & Hoseney, R.C. 1979. Grain sorghum condensed tannins. l. Isolation, estimation, and selective adsorption by starch. Cereal Chem., 56: 310-314.**

**Deatherage, W.L., McMasters, M.M. & Rist, C.E. 1955. A partial survey of amylose content in starch from domestic and foreign varieties of corn, wheat and sorghum and from some other starch-bearing plants. Trans. Am. Assoc. Cereal Chem. 13: 31-42.**

**DeMaeyer, E.M., Lowenstein, F.W. & Thilly, C.H. 1979. The control of endemic goitre. Genve, OMS.**

**Dendy, D.A.V. 1992. Composite flour - past, present and the future: a review with special emphasis on the place of composite flour in the semi-arid zones. In M.l. Gomez, L.R. House, L.W. Rooney & D.A.V. Dendy, ds. Utilizution of songhumand millets, p. 67-73. Patancheru, Inde, ICRISAT.**

**Deosthale, Y.G. 1980. Nutrition dimension of high yielding and hybrid crop varieties: locational and varietal differences in nutritional value. In M Mohan Ram & V. Ramadas Murthy, ds. Proceedings of workshop on strategies in agriculture sector for nutritional goals, 21-22 juillet 1980. Hyderabad, Inde, National Institute of Nutrition.**

**Deosthale, Y.G. & Belavady, B. 1978. Mineral and trace element composition of sorghum grain: effect of variety, location and application of the nitrogen fertilizer. Indian J. Nutr. Diet. 15: 302-308.**

**Deosthale, Y.G. & Gopalan, C. 1974. The effect of molybdenum levels in sorghum (Sorghum vulgare Pers.) on uric acid and copper excretion in man. Br. .1. Nutr 31: 351 -355.**

**Deosthale, Y.G., Krishnamachari, K.A.V.R. & Belavady, B. 1977. Copper, molybdenum and zinc in rice, sorghum and pearlmillet grains from fluorosis and nonfluorosis areas of**

**Andhra Pradesh. Indian J. Agric. Sci. 47: 333-335.**

**Deosthale, Y.G. & Mohan V.S. 1970. Locational differences in protein, lysine and leucine content of sorghum varieties. Indian .1. Agric. Sci. 40: 935-941.**

**Deosthale, Y.G., Nagarajan, V. & Visweswar Rao, K. 1972. Some factors influencing the nutrient composition of sorghum grain. Indian J. Agric .Sci. 42: 100-108.**

**Deosthale, Y.G., Visweswara Rao, K., Nagarajan, V. & Pant, K.C. 1971. Varietal differences in protein and amino acids of grain bajra (Pennisetum typhoides). Indian J. Nutr.: Diet. 8: 301-308.**

**Deosthale, Y.G., Visweswar Rao, K. & Pant, K.C. 1972. Influence of the levels of N fertilizer on the yield, protein and amino acids of pearl-millet ( Pennisetum typhoides (Burm. f.) Stapf & C.E. Hubb.). Indian .l. Agric. Sci. 42: 872-876.**

**Derman, D.P., Bothwell, T.H., Torrance, J.D., Bezwoda, W.R., MacPhail, A.P., Kew, M.C., Sayers, M.H., Disler, P.B. & Charlton, R.W. 1980. Iron absorption from maize (Zea mays) and sorghum (Sorghum vulgare) beer. Br. J. Nur.: 43: 271-279.**

**Desikachar, H.S.R. 1975. Processing of maize, sorghum and millets for food uses. J. Sci. Ind. Res. 34: 231 -237.**

**Desikachar, H.S.R. 1977. Processing of sorghum and millets for versatile food uses in India. In D.A.V. Dendy, d. Proceedings of a symposium on sorghum and millets for human food Vienne, l l - 12 mai 1976, p. 41-45. Londres, Institut des produits tropicaux.**

**Desikachar, H.S.R. 1982. Pearling and milling studies on sorghum. In L.W. Rooney & D.S. Murty, ds. Proceedings of the International Symposium on Sorghum Grain Quality Hyderabad, Inde, 28-31 octobre 1981, p. 194-199. Patancheru, Inde, ICRISAT.**

**Desikachar, H.S.R. & Chandrashekar, A. 1982. Quality of sorghum for use in Indian foods. In L.W. Rooney & D.S. Murty, ds. Proceedings of the International. Symposium on Sorghum Grain Quality, Hyderabad, Inde, 28-3 1 octobre 1981, p. 262268. Patancheru, Inde, ICRISAT.**

**Dewalt, K.M. & Thompson, K.S. 1983. Sorghum and nutritional strategies in southern Honduras. Pract.Anthropol., 5: 5-16. de Wit, J.P. & Schweigart, F. 1970. The potential role of pearl millet as a food in South Africa.. S. Afr. Med. J. 44: 364-366.**

**Deyoe, C.W. & Shellenberger,.l.A. 1965. Amino acids and proteins in sorghum grain. J. Agric. Food Chent. 13: 446-450.**

**Dhankher, N & Chauhan, B.M. 1987. Et`fect of temperature and fermentation time on phytic acid and polyphenol content of rabaadi - a fermented pearl millet food.. J. Food Sci 52: 828-829.**

**Dhindsa, K.S., Dhillon, S. & Sood, D.R. 1982. Nutritional quality of millets. MILWAI New .s1. 1: 2.**

**Doggett, H. 1988. Sorghum Londres, Longman Scientific and Technical.**

**Doherty, C., Faubion, J.M. & Rooney, L.W. 1982. Semiautomated determination of phytate in sorghum and sorghum products. Cereal Chem. 59: 373-378.**

**Doraiswamy, T.R., Singh, N. & Daniel, V.A. 1969. Effects of supplementing ragi (Eleusine coracana) diets with lysine or leaf protein on the growth and nitrogen metabolism of children. B.r. J. Nutr. 23: 737-743.**

**Dreher, M.L., Dreher, C.J. & Berry, J.W. 1984. Starch digestibility of foods. A nutritional perspective. CRC Crit. Rev. Food Sci. Nutr 20: 47-71.**

**Dreyer, D.L., Reese, J.C. & Jones, K.C. 1981. Aphid feeding deterrents in sorghum: bioassay. isolation and characterization. J. Chem. Ecol. 7: 273-284.**

**Dublish, R.K., Chauhan, G.S. & Bains, G.S. 1988. Nutritional quality of extruded rice, ragi and defatted soy flour blends. J. Food Sci. Technol.. 25: 35-8.**

**Earp, C.F., Doherty, C.A., Fulcher, R.G. & Rooney, L.W. 1983. Beta-Glucans in the caryopsis of Sorghum bicolor ( L) Moench. Food Microstruc. 2: 183- 188.**

**Eastman, P. 1980. An end to pounding. A new mechartical flour milling .system in use in Africa. Ottawa, Canada, Centre de recherche pour le dveloppement international. 63 p.**

**Eggum, B.O. & Christensen, K.D. 1975. Influence of tannin on protein utilization in feedstuffs with special ret`erence to barley. In Breeding for seed protein improvement using nuclear techiques p. 135-143. Vienne, Agence internationale de l'nergie atomique.**

**Eggum, B.O., Monowar, L., Bach Knudsen, K.E., Munck, L. & Axtell, J. 1983. Nutritional quality of sorghum and sorghum foods from Sudan. J. Cereal Sci. 1: 127137.**

**Ejeta, G. & Axtell, J. 1987. Protein and lysine levels in developing kernels of normal and high-lysine sorghum. Cereal Chem. 64: 137-139.**

**Elmalik, M., Klopfenstein, C.F., Hoseney, R.C. & Bates, L.S. 1986. Digestibility and nutritional quality of sorghum grain with contrasting kernel characteristics. Nutr-. Rep. Int. 34: 811 -820.**

**Emiola, L.O. & de la Rosa. 1981. Characterization of pearl millet non starchy polysaccharides. J. Food Sci., 46: 781 -785.**

**Eusebio, E. & Elliot, J.S. 1967. Effect of trace metals on the crystallization of calcium oxalate. Invest. Urol. 4: 431 -435.**

**FAO. 1965. Protein requirements. FAO Nutrition Meeting Report Series No. 37. Rome.**

**FAO. 1970a. Teneur des aliments en acides amins et donnes biologique sur les protines. Etudes nutritionnelles de la FAO. n 24. Rome.**

**FAO. 1970b. Handling and storage of food grains in tropical and sfubtropical areas. FAO Agricultural Development Paper No. 90. Rome. 35 p.**

**FAO. 1981. Agriculture: Horizon 2000. Rome.**

**FAO. 1982. The potential for industrial processing of sorghum for baking and allied food industries in Africa. Report of the Regional Workshop on Composite Flours, Shambat, Soudan, 7 dcembre 1981. Rome. 32 p.**

**FAO. 1988. Structure et caractristiques de l''conomie mondiale du sorgho, CCP:GR 88/4. Rome. 16 p.**

**FAO. 1990a. Manuels sur le contrle de la qualit des produits alimentaires 10. Training in mycotoxins analysis. Etude FAO: Alimentation et nutrition 14/ 10. Rome.**

**FAO. 1990b. Structure et caractristiques de 1'conomie mondiale du mil. CCP:GR 90/4. Rome. 15 p.**

**FAO. 1991. Annuaire de la production 1990. Vol. 44. Srie statistique de la FAO n 99. Rome.**

**Fapojuwo, O.O.. Maga, J.A. & Jansen, G.R. 1987. Effect of extrusion cooking on in vitro protein digestibility of sorghum. J. Food Sci. 52: 218-219.**

**Faure, J.C. 1992. Sorghum and maize pasta and extruded products. In M.l. Gomez, L.R. House, L.W. Rooney & D.A.V. Dendy, ds. Utilization of sorghum and millets p. 75-82. Patancheru, Inde, lCRISAT.**

**Freeman, J.E., Kramer, N.W. & Watson, S.A. 1968. Gelatinization of starches from corn (Zea mays L.) and sorghum (Sorghum bicolor L. Moench). Effects of genetic and environmental factors. Crop. Sci. 8: 409-413.**

**Frey, K.J. 1977. Protein of oats. Z. Pfianzenzcht.. 78: 185-215.**

**Gaitan, E., Lindsay, R.H., Reichert, R.D., Ingbar, S.H., Cooksey, R.C., Legan, ,J., Meydrech, E.F., Hill, J. & Kubota, K. 1989. Antithyroid and goitrogenic effects of millets: role of c - glycosyl flavones. J. Clin. Endocrinol. Metab. 68: 707-714.**

**Galiba, M., Rooney, L.W., Waniska, R.D. & Miller, F.R. 1987. The preparation of sorghum and millet couscous in West Africa. Cereal Foods World 32: 878884.**

**Ganapathy, N.S., Chitra, R.G. & Gokhale, S.K. 1957. The effect of the protein of Italian**

**millet (Setaia italica) on nitrogen retention in albino rats. Indian J. Med. Res. 45: 395-399.**

**Gebrekidan, B. & Gebre Hiwot, B. 982. Sorghum injera preparations and quality parameters. In L.W. Rooney & D.S. Murty, ds. Proceedings of the International .Symposium on Sorghum Grain Quality Hyderabad, Inde, 28-31 octobre 1981, p. 55-66. Patancheru, Inde, ICRISAT.**

**Geervani, P. & Eggum, B.O. 1989. Nutrient composition and protein quality of minor millets. Plant Foods Hum Nutr. 39: 201-208.**

**Geervani, P. & Vimala, V. 1993. Operational research on development of sorghum food enterprises for alternative uses and supplementary feeding. Hyderabad, Inde , College of Home Science , Andhra Pradesh Agricultural University.**

**Ghafooranissa & Narasinga Rao, B.S. 1973. Effect of leucine on enzymes of the tryptophan-niacin metabolic pathway in rat liver and kidney. Biochem. J. 134: 425 430.**

**Ghosh, H.P., Sarkar, P.K. & Guha, B. 1963. Distribution of the bound form of nicotinic acid in natural materials. J. Nutr. 79: 451 -453.**

**Gillooly, M., Bothwell, T.H., Charlton, R.W., Torrance, J.D., Bezwoda, W.R.,**

**MacPhail, A.P., Derman, D.P., Novelli, L., Morrall, P. & Mayet, F. 1984. Factors affecting the**

**absorption of iron from cereals. Br. J. Nutr. 51: 37-46.**

**Goldsmith, G.A., Gibbens, J., Unglaub, W.G. & Miller, O.N. 1956. Studies of niacin requirement in man. III Comparative effects of diets containing limetreated and untreated corn in the production of experimental pellagra. Am. J. Clin. Nutr. 4: 151 160.**

**Gopalan, C. & Srikantia, S.G. 1960. Leucine and pellagra. Lancet 1: 954-957.**

**Gopalan, C. & Vijayaraghavan, K., ds. l969. Nutrition atlas of India. Hyderabad, Inde, National Institute of Nutrition.**

**Goswamy, A.K., Sehgal, K.L. & Gupta, B.K. 1970. Chemical composition of bajra grains - 3. Indian inbreds. Indian J. Nutr. Diet. 7: 5-9.**

**Goswamy, A.K., Sehgal, K.L. & Sharma, K.P. 1969. Chemical composition of bajra grains - 1. African entries. Indiait. J. Nutr. Diet.. 6: 287-290.**

**Goswamy, A.K., Sharma, K.P. & Gupta, B.K. 1969. Chemical composition of bajra grains - 2. American entries. Indian .1. Nutr. Diet. 6: 291 -294.**

**Goswamy, A.K., Sharma, K.P. & Sehgal, K.L. 1970. Chemical composition of bajra grains - 4. Indian varieties. Indian J. Nutr Diet. 7: 67-70.**

**Graham, G.G., MacLean, W.C. Jr, Morales, E., Hamaker, B.R., Kirleis, A.W., Mertz, E.T. & Axtell, J.D. 1986. Digestibility and utilization of protein and energy from Nasha, a traditional Sudanese fermented sorghum weaning food. .I. Nutr. 116: 978984.**

**Griffths, D.W. 1985. The inhibition of digestive enzymes by polyphenolic compounds. Exp. Biol. Med. 199: 504-516.**

**Gupta, R.K. & Haslam, E. 1980. Vegetative tannins: structure and biosynthesis. ln J.H. Hulse, d. Polyphenols in cereals and legumes p. 15-24. Ottawa, Canada, Centre de recherche pour le dveloppement international.**

**Hamaker, B.R., Kirleis, A.W., Mertz, E.T. & Axtell, J.D. 1986. Effect of cooking on the protein profiles and in vitro digestibility of sorghum and maize. J. Agric. Food Chem.. 34: 647-649.**

**Harbers, L.H. 1975. Starch granule structural changes and amylolytic patterns in processed sorghum grain. .1. Anim. Sci. 41: 1496- 1501.**

**Harlan, J.R. & de Wet, J.M.J. 1972. A simplified classification of cultivated sorghum. Crop Sci., 12: 172- 176.**

**Harris, H.B. & Burns, R.E. 1970. Influence of tannin content on preharvest germination in sorghum Agron.J., 62: 835-836.**

**Harris, H.B. & Burns, R.E. 1973. Relationship between tannin content of sorghum grain and preharvest seed molding. Agron. J., 65: 957-959.**

**Hemanalini, G., Umapathy, K.P., Rao, J.R. & Saraswathi, G.1980. Nutritional evaluation of sprouted ragi. Nun: Rep. Int., 22: 271 -277.**

**Hewitt, D. & Ford, ,I.E. 1982. Influence of tannins on the protein nutritional quality of food grains. Proc Nutr. Soc., 41: 7-17.**

**Hibberd, C.A., Wagner, D.G., Schemm, R.L., Mitchell, F,.D. Jr, Weibel, D.E. & Hintz, R.L,. 1982. Digestibility characteristics of isolated starch from sorghum and corn grain. J. Anim. Sci., 55: 1490- 1497.**

**Horan, F.E,. & Heider, M.F. 1946. A study of sorghum and sorghum starches. Cereal Chem., 23: 492-503.**

**Hoseney, R.C., Andrews, D.J. & Clark, H. 1987. Sorghum and pearl millet. In R.A. Olsen & K.J. Frey, ds. Nutritional quality of cereal grains: genelic and agronomic improvement, p. 397-456. Madison, Wisconsin, Etats-Unis, American Society of Agronomy.**

**Howe, E.E. & Gilfillan, E.W. 1970. Limiting nutrients in Cereal grains for the growth of the laboratory rat. Indian J. Nutr. Diet. 7: 17-20.**

**Hubbard, J.E., Hall, H.H. & Earle, F.R. 1950. Composition of the component parts of the sorghum kernel. Cereal Chem.. 27: 415-420.**

**Hulse, J.H., Laing, E.M. & Pearson, O.E. 1980. Sorghum and the millets: their composition and nutritive value. New York, Academic Press. 997 p.**

**Ibrahim, S., Fisher, C., Alaily, H.E., Soloman, H. & Anwar, A. 1988. Improvement of the nutritional quality of Egyptian and Sudanese sorghum grains by the addition of phosphates. Br Poult. Sci., 29: 721 -728.**

**Ifon, E.E. 1981. Bioavailability to rats of the iron contents in selected cereals and pulses. Nutr. Rep Int. 24: 25-3U.**

**Indira, R. & Naik, M.S. 1971. Nutrient composition and protein quality of some minor millets. Inian J. Agric . Sci., 41: 795-797.**

**Iyakaremye, C. & Twagirumukiza, E. 1978. Note on the brewing value of sorghum. Bull. Agric . Rwanda 11: 35-41.**

**Jambunathan, R. 1980. Improvement of the nutritional quality of sorghum and pearl millet. Food Nutr.: Bull.. 2: 11 - 16.**

**Jambunathan, R., Butler, L.G., Bandyopadhyay, R. & Mughogho, L.K. 1986. Polyphenol**

**concentrations in grain, leaf and callus tissues of mold-susceptible and mold-resistant sorghum cultivars. J. Agric. Food Chem., 34: 425-429.**

**Jambunathan, R., Singh, U. & Subramanian, V. 1984. Grain quality of sorghum, pearl millet, pigeonpea and chickpea. In K.T. Achaya, d. Interfaces between aagriculture nutrition and food science. Proceedings of a workshop, Patancheru, Inde, 10-12 novembre 1981, p. 4760. Tokyo, Japon, Universit des Nations Unies.**

**Jambunathan, R. & Subramanian, V. 1988. Grain quality and utilization of sorghum and pearl millet. In Biotechnology in tropical crop improvement. Proceedings of the International Biotechnology Workshop, Patancheru, Inde, 12-15 janvier 1987, p. 133139. Patancheru, ICRISAT.**

**James, A.W. & Nyambati, G.M. 1987. New food uses for sorghum in Kenya. Approp. Technol., 14: 24-26.**

**Jellum, M.D. & Powell, J.B. 1971. Fatty acid composition of oil from pearl millet seed. Agron. J., 63: 29-33.**

**Joffe, A.Z. 1965. Toxin production by cereal fungi causing toxic alimentary aleukia in man. In G.N. Wogan, d. Mycotoxins in foodstuffs, Qs, p. 77-85. Cambridge, Massachusetts, Etats-Unis, MIT Press.**

**Jones, R.W., Beckwith, A.C., Khoo, U. & Inglett, G.F. 1970. Protein composition of proso millet. J. Agric . Food Chem., 18: 37-39.**

**Joseph, K., Kurien, P.P., Swaminathan, M. & Subramanyan, V. 1959. The metabolism of nitrogen, calcium and phosphorus in undernourished children. Br. J. Nutr., 13: 213-218.**

**Kamath, M.V. & Belavady, B. 1980. Unavailable carbohydrates of commonly consumed Indian foods. J. Sci. Food Agric ., 31: 194-202.**

**Kapu, M.M., Balarabe, M.L. & Udomah, M.G. 1989. Effect of the extent of insect damage on the protein content of maize, guinea corn and cowpeas from Zaria, Nigria. Nutr Rep. Int., 40: 1159- 1163.**

**Karim, A. & Rooney, L.W. 1972. Characterization of pentosans in sorghum grain. J. Food Sci., 37: 369-371.**

**Kazanas, N. & Fields, M.L. 1981. Nutritional improvement of sorghum by fermentation. J. Food Sri., 46: 819-821.**

**Kelley, T.G., Parthasarathy Rao, P. & Singh, R.P. 1992. Trends in sorghum production and utilization in Asia. Economics Group, Resource Management Programme, Progress Report 108. Patancheru, Inde, ICRISAT.**

**Kent, N.L. 1983. Technology of cereals. Oxford, Royaume-Uni, Pergamon Press.**

**Khalil, J.K. & Sawaya, W.N. 1984. Mineral and vitamin contents of Saudi Arabian pearl millet, flour and bread. Cereal Chem., 61: 301-304.**

**Khalil, J.K., Sawaya, W.N., Safi, W.J. & Al-Mohammed, H.M. 1984. Chemical composition and nutritional quality of sorghum flour and bread. Qual. Plant. Plant Foods Hum. Nutr.: 34: 141-150.**

**Klopfenstein, C.F., & Hoseney, R.C. 1987. Cholesterol-lowering effect of beta-glucanenriched bread. Nutr. Rep. Int., 36: 1091-1098.**

**Klopfenstein, C.F., Hoseney, R.C. & Leipold, H.W. 1983a. Goitrogenic effects of pearl millet diets. Nutr. Rep. Int. 27: 1039-1047.**

**Klopfenstein, C.F., Hoseney, R.C. & Leipold, H.W. 1983b. Further studies on the goitrogenic effects of pearl millet diets. Nutr. Rep. Int. 28: 1137-1144.**

**Klopfenstein, C.F., Hoseney, R.C. & Leipold, H.W. 1985. Nutritional quality of pearl millet and sorghum grain diets and a pearl millet weanling food. Nutr. Rep. Int. 31: 287297.**

**Klopfenstein, C.F., Hoseney, R.C. & Varriano-Marston, E. 1981. Effects of ascorbic acid in guinea pigs fed millet and sorghum grain diets. Nutr. Rep. Int. 24: 1099- 1107.**

**Klopfenstein, C.F., Leipold, H.W. & Cecil, J.E. 1991. Semiwet milling of pearl millet for reduced goitrogenicity. Cereal Chem.. 68: 177-179.**

**Klopfenstein, C.F., Varriano-Marston, E. & Hoseney, R.C. 1981 a. Cholesterollowering effect of sorghum diet in guinea pigs. Nutr. Rep. Int.. 24: 621 -627.**

**Klopfenstein, C.F., Varriano-Marston, E. & Hoseney, R.C. 198 lb. Effects of ascorbic acid in casein vs. sorghum grain diets in guinea pigs. Nutr. Rep. Int. 24: 1017-1028.**

**Krishnamachari, K.A.V.R. 1976. Further observations on the syndrome of endemic genu valgum of South India. Indian .1. Med. Res., 64: 284-291.**

**Krishnamachari, K.A.V.R. & Bhat, R.V. 1976. Poisoning by ergoty bajra (pearl millet) in man. Indian J. Med. Res., 64: 1624-1628.**

**Krishnamachari, K.A.V.R. & Krishnaswamy, K. 1974. An epidemiological study of the syndrome of genu valgum among residents of endemic areas for fluorosis in Andhra Pradesh. Indian .1. Med. Res., 62: 1415- 1423.**

**Krishnaswamy, K., Bapu Rao, S., Raghuram, T.C. & Srikantia, S.C., 1976. Effect of vitamin B6 on leucine-induced changes in human subjects. Am. J. Clin. Nutr. 29: 177181.**

**Krishnaswamy, K. & Gopalan, C. 1971. Effect of isoleucine on skin and**

**electroencephalogram in pellagra. Lancet 2: 1167-1169.**

**Kulkarni, K.D., Parlikar, D. & Bhagwat, S.M. 1987. Product application studies on sorghum malt: cookies, weaning food and beer wort. In U.M. Ingle, D.N. Kulkarni & S.S. Thorat, ds. Proceedings of the National Seminar an Technology and Applications for Alternative Uses of Sorghum p. 130- 143. Parbhani, Maharashtra, Inde, Marathwada Agricultural University.**

**Kuppuswamy, S., Srinivasan, M. & Subramanian, V. 1958. Protein in foods. Special Report Series No. 33. New Delhi, Inde, Indian Council of Medical Research.**

**Kurien, P.P., Narayanarao, M., Swaminathan, M. & Subrahmanyan, V. 1960. The metabolism of nitrogen, calcium and phosphorus in undernourished children. 6. The effect of partial or complete replacement of rice in poor vegetarian diets by kaffir corn (Sorghum vulgare). Br. J. Nutr. 14: 339-345.**

**Kurien, P.P., Swaminathan, M. & Subrahmanyan, V. 1961. The metabolism of nitrogen, calcium and phosphorus in children on a poor Indian diet based on bajra (Pennisetum typhoideum). Ann. Biochem. Exp. Med. 21: 41 -46.**

**Lai, C.C. & Varriano-Marston, E. 1980. Lipid content and fatty acid composition of free and bound lipids in pearl millets. Cereal Chem.. 57: 271 -274.**

**Lakshmalah, N. & Srikantia, S.(G. 1977. Fluoride retention in humans on sorghumand rice-based diets. Indian J. Med. Res.. 65: 543-548.**

**Leach, H.W. 1965. Gelatinization of starch. In R.L. Whistler & E.F. Paschall, ds. Starch: chemistry and technology. Vol. 1, Fundamental aspects p. 289. New York, Academic Press.**

**Lorenz, K. 1983. Tannins and phytate content in proso millets (Panicum miliuceum). Cereal Chem.. 60: 424-426.**

**Lorenz, K. & Dilsaver, W. 1980. Rheological properties and food applications of proso millet flours. Cereal Chem.. 57: 21 -24.**

**Lorenz, K. & Hinze, C,. 1976. Functional characteristics of starches from proso and foxtail millets. J. Agric. Food Chem. 24: 911 -914.**

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**MacLean, W.C. Jr, Lpez de Romana, G., Gastanaduy, A. & Graham, G.G. 1983. The effect of decortication and extrusion on the digestibility of sorghum by preschool children. .1. Nutr. 113: 2071 -2077.**

**MacLean, W.C. Jr, Lpez de Romaa, G., Placko, R.P. & Graham, G.G.1981. Protein quality and digestibility of sorghum in preschool children: balance studies and plasma tree amino acids. J. Nutr. 111: 1928-1936.**

**MacMasters, M.M., Hinton, J.J.C. & Bradbury, D. 1971. Microscopic structure and composition of the wheat kernel. In Y. Pomeranz, d. Wheat: chemistry and technology. p. 51 - 113. St Paul. Minnesota, Etats-Unis, American Association of Cereal Chemists. 2e d.**

**Malleshi, N.G., Daodu, M.A. & Chandrasekhar, A. 1989. Development of weaning food formulations based on malting and roller drying of sorghum and cowpea. Int. .1. Food Sci. Technol., 24: 511 -519.**

**Malleshi, N.G. & Desikachar, H.S.R. 1981. Varietal differences in puffing quality of ragi (Eleusine coracana). J. Food Sci. Technical.. 18: 30-32.**

**Malleshi, N.G. & Desikachar, H.S.R. 1982. Formulation of a weaning food with low hot paste viscosity based on malted ragi (Eleusine coracana) and green gram (Phaseolus radiatus). J. Food Sci. Technol. 19: 193- 197.**

**Malleshi, N.G. & Desikachar, H.S.R. 1986a. Studies on comparative malting characteristics of some tropical cereals and millets.J. Inst. Brew., 92: 174-176.**

**Malleshi, N.G. & Desikachar, H.S.R. 1986b. Nutritive value of malted millet flours. Qual. Plant. Plant Foods Hum. Nutr. 36: 191-196.**

**Malleshi, N.G., Desikachar, H.S.R. & Venkat Rao, S. 1986. Protein quality evaluation of a weaning food based on malted ragi and green gram. Qual. Plant. Plant Foods Hum. Nutr., 36: 223-230.**

**Manjunath, N.H., Veerbhadrappa, P.S. & Virupaksha, T.K.1981 . Purification and characterization of trypsin inhibitors from finger millet (Eleusine coracana Gaertn). Indian J. Biochem. Biophys. 18: 105-110.**

**Matlon, P.J.1990. Improving productivity in sorghum and pearl millet in semi-arid Africa. Food Res. Inst. Stud. 22: 1-43.**

**Mbofung, C.M.F. & Ndjouenkeu, R. 1990. Influence of milling method and peanut extract**

on in vitro iron availability from maize and sorghum flour gruels. J. Food Sci., 55: 1 657-1659, 1675.

McMillan, W.W., Wiseman, B.R., Burns, R.E., Harris, H.B. & Greene, G.L. 1972. Bird resistance in diverse germplasm of sorghum. Agron. J., 64: 821 -822.

McNeill, J.W., Potter, G.D., Riggs, J.K. & Rooney, L.W. 1975. Chemical and physical properties of processed sorghum grain carbohydrates. J. Anim.. Sci., 40: 335-341.

Mehansho, H., Butler, L.G. & Carlson, D.M.1987. Dietary tannins and salivary prolinerich proteins: interactions, induction and defense mechanisms. Annu. Rev. Nutr. 7: 423440.

Mertz, E.T., Hassen, M.M., Cairns-Whittern, C., Kirleis, A.W., Tu, L. & Axtell, J.D. 1984. Protein digestibility of proteins in sorghum and other major cereals. Proc. Natl. Acad. Sci. USA, 81: 1 -2.

Miche, J.C., Alary, R., Jeanjean, M.F. & Abecassis, J. 1977. Potential use of sorghum grains in pasta processing. In D.A.V. Dendy, d. Proceedings of a symposium an sorghum and millets for human food, Vienne, 11 - 12 mai 1976, p. 27-35. Londres, Institut des produits tropicaux.

Monteiro, P.V., Gopal, D.N., Virupaksha, T.K. & Ramachandra, G. 1988. Chemical

**composition and in vitro protein digestibility of Italian millet (Setaria italica). Food Chem.. 29: 19-26.**

**Monteiro, P.V., Virupaksha, T.K. & Rajagopol Rao, D. 1982. Proteins of Italian millet: amino acid composition, solubility fractionation and electrophoresis of protein fractions.J. .Sci. Food Agric.. 33: 1072-1079.**

**Morton, J.F. 1970. Tentative correlations of plant usage and esophageal cancer zones. Econ. Bot., 24: 217-226.**

**Mosha, A.C. & Svanberg, U. 1983. Preparation of weaning foods with high nutrient density using flour of germinated cereals. Food Nutr. Bull., 5: 10- 14.**

**Muindi, P.J. & Thomke, S. 198 1. The nutritive value for rats of high- and low-tannin sorghums treated with Magadi soda. J. Sci. Food Agric., 32: 139- 145.**

**Mukuru, S.Z. 1992. Traditional technologies in small grain processing. In M.I. Gomez, L.R. House, L.W. Rooney & D.A.V. Dendy, ds. Utilization of sorghum and millets, p. 47-56. Patancheru, Inde, lCRlSAT.**

**Munck, L., Bach Knudsen, K.E. & Axtell, J.D. 1982. Milling processes and products as related to kernel morphology. In L.W. Rooney & D.S. Murty, ds. Proceedings of the**

International Symposium on Sorghum Grain Qua/ity, Hyderabad, Inde, 28-31 octobre 1981, p. 200-210. Patancheru, Inde. ICRISAT.

Muralikrishna, G., Paramahans, S.V. & Tharanathan, R.N. 1982. Carbohydrate makeup of minor millets. Starch, 34: 397-401.

Murty, D.S., Patil, H.D. & House, L.R. 1982. Sankati quality evaluation of sorghum cultivars. In L.W. Rooney & D.S. Murty, ds. Proceedings of the International Symposium on Sorghum Grain Quality, Hyderabad, Inde, 2831 octobre 1981, p. 36-38. Patancheru, Inde, ICRISAT.

Murty, D.S., Patil, H.D., Prasada Rao, K.E. & House, L.R. 1982. A note on screening the Indian sorghum collection for popping quality. J. Food Sci. Technol. 19: 79-80.

Murty, D.S., Singh, U., Suryaprakash, S. & Nicodemus, D.S. 1985. Soluble sugars in five endosperm types of sorghum. Cereal Chem. 62: 150- 152.

Murty, D.S. & Subramanian, V. 1982. Sorghum roti. 1. Traditional methods of consumption and standard procedures for evaluation. In L.W. Rooney & D.S. Murty, ds. Proceedings of the International .Symposium on Sorghum Grain Quality Hyderabad, Inde, 28-31 octobre 1981, p. 73-78. Patancheru, Inde, ICRISAT.

Mwasaru, M.A., Reichert, R.D. & Mukuru, S.Z. 1988. Factors affecting the abrasive

**dehulling efficiency of high-tannin sorghum. Cereal Chem.. 65: 171 174.**

**Naik, M.S. 1968. Lysine and tryptophan in protein fractions of sorghum. Indian J. Genet. Plant Breed., 28: 142-146.**

**Nakagawa, l., Ohguri, S., Sasaki, A., Kajimoto, M., Sasaki, M. & Takahashi, T. 1975. Effects of excess intake of leucine and valine deficiency on tryptophan and niacin metabolites in humans.J. Nutr.: 105: 1241-1252.**

**Nakagawa, l. & Sasaki, A. 1977. Effect of an excess intake of leucine, with and without additions of vitamin B6 and/or niacin, on tryptophan and niacin metabolism in rats. J. Nutr. Sci. Vitaminol., 23: 535-548.**

**Naren, A.P. & Virupaksha, T.K. 1990. Effect of sulfur deficiency on the synthesis of ocsetarin, a methionine-rich protein of Italian millet. Cereal Chem. 67: 136138.**

**Nattress, L.A., Mehta, T., Mitchell, M.E. & Finney, P.L. 1987. Eormulation and nutritive value of weaning food from germinated food grains. Nutr. Res. 7: 1309- 1320.**

**Nawar, I.A., Clark, H.E., Pickett, R.C. & Hegsted, D.M. 1970. Protein quality of selected lines of Sorghum vulgare for the growing rat. Nutr Rep. Int. 1: 75**

**Ngoddy, P.O. 1989. Sorghum milling in Nigeria. a review of industrial practice, research and**

**innovations.. Paper presented at the Symposium on the Current Status and Potential of Industrial Uses of Sorghum in Nigria, Kano, Nigeria, 4-6 dcembre.**

**Nicol, B.M. & Phillips, P.G. 1978. The utilization of proteins and amino acids in diets based on cassava (Manihot utilissima) rice or sorghum (Sorghum sativa) by young Nigerian men of low income. Bn. J. Nutr., 39: 271-287.**

**Nishimuta, J.F., Sherrod, L.B. & Furr, R.D. 1969. Digestibility of regular, waxy and white sorghum grain rations by sheep. In Proceedings of the meeting of the Western Section, American Society of Animal Science, Laramie, Wyoming, Etats-Unis, juillet 1969, p. 259.**

**Nout, M.J.R., Hautvast, J.G.A.J., van der Haar, F., Marks, W.E.W. & Rombouts, F.M. 1988. Formulation and microbiological safety of cereal-based weaning foods. In D. Alnwick, S. Moses & O.G. Schmidt, ds. Improving young childfeeding in eastern and southern Africa, p. 245-260. Nairobi, Kenya, Centre de recherche pour le dveloppement international.**

**Nwokolo, E. 1987. Composition and availability of nutrients in some tropical grains and oilseeds. Nutr., Rep. Int. 36: 631-640.**

**Obilana, A.T. 198S. Sorghum for industrial use: approach towards crop improvementt in an economically changing Nigeria. Paper presented to the Food Industrialists at Cadbury Nigeria Ltd, Lagos, Nigria, 30 janvier.**

**Orizoba, I.C. & Atii, J.V. 1991. Effect of soaking, sprouting, fermentation and cooking on nutrient composition and some anti-nutritional factors of sorghum (Guinesia) seeds. Plant Foods Hum. Nutr., 41: 203-212.**

**Odunfa, S.A. & Adeyele, S. 1987. Sugar changes in fermenting sorghum during preparation of ogi-baba gruel. J. Food Agric. 2: 95-98.**

**Okafor, N. & Aniche, G.N. 1987. Studies on the brewing of lager beer 1`rom Nigerian sorghum. J. Food Sci. Technol., 24: 131 - 134.**

**Okeiyi, E.C. & Futrell, M.F. 1983. Evaluation of protein quality of formulations of sorghum grain flour and legume seeds. Nutr. Rep. Int. 28: 451 -461.**

**Olatunji, O., Adesina, A.A. & Koleoso, O.A.1989. Use of sorghum as compasite flour in baking Paper presented at the Symposium on the Current Status and Potential of Industrial Uses of Sorghum in Nigeria, Kano, Nigria, 4-6 dcembre.**

**Ollitrault, P., Escoute, J. & Noyer, J.L. 1989. Polymorphisme enzymatique des sorghos. l. Description de 11 systmes enzymatiques - Dterminisme et liaisons gntiques. Agron. Trop. 44: 203-210.**

**OMS (Organisation mondiale de la sant. Besoins nergtiques et besoins en protines.**

**Rapport d'une consultation conjointe d'experts FAO/OMS/UNU. Srie de rapports techniques 724. Genve.**

**O'Neill, C.O., Clarke, G., Hodges, G...lordan, P., Newman, R., Pan, Q.-G., Liu, F.S., Ge, M., Chang, Y.M. & Toulson, E. 1982. Silica fragments surrounding oesophageal tumours in patients in northern China. Lancet 1: 1202-1206.**

**Oniang'O, R. & Alnwick, D.J. 1988. Weaning foods in Kenya: tradition and trends. In D. Alnwick, S. Moses & O.G. Schmidt, ds. Improving young child feeding in eastern and southern Africa p. 76-80. Nairobi, Kenya, Centre de recherche pour le dveloppement international.**

**Opoku, A.R., Ohenhen, S.O. & Ejiofor, N. 1981. Nutrient composition of millet (Pennisetum typhoides) grains and malt. J. Agric. Food Chem, 29: 1247- 1248.**

**Osagie, A.U. & Kates, M. 1984. Lipid composition of millet (Pennisetum americanum) seeds. Lipids, 19: 958-965.**

**Osman, A.K., Basu, T.K. & Dickerson, J.W.T. 1983. A goitrogenic agent from millet (Pennisetum typhoides) in Darfur Provinces, western Sudan. Ann. Nutr., Metab. 27: 1418.**

**Osman, A.K. & Fatah, A.A. 1981. Factors other than iodine deficiency contributing to the**

**endemicity of goitre in Darfur Province, Sudan. J. Hum. Nutr., 35:302309.**

**Osuntogun, B.O., Adewusi, S.R.A., Ogundiwin, J.O. & Nwasike, C.C. 1989. Effect of cultivar, steeping, and malting on tannin, total polyphenol, and cyanide content of Nigerian sorghum. Cereal Chem.. 66: 87-89.**

**Pal, A., Wagle, D.S. & Sheorain, V.S. 1976. Some enzymatic studies on bajra (Pennisetum typhoides) and barley (Hordeum vulgare) during malting.J. Food Sci. Technol.. 13: 75-78.**

**Panasiuk, O. & Bills, D.D. 1984. Cyanide content of sorghum sprouts.J. Food Sci., 49: 791-793.**

**Pandit, C.G., Raghavachari, T.N.S., Rao, D.S. & Krishnamurti, V. 1940. Endemic fluorosis in South India. A study of the factors involved in the production of mottled enamel in children and severe bone manifestations in adults. Indian J. Med. Res. 28: 533-540.**

**Pant, K.C. 1975. High nicotinie acid content in two Ethiopian sorghum lines. J. Agric. Food Chem. 23: 608-609.**

**Pant, K.C. & Susheela, T.P. 1977. Effect of storage and insect infestation on the chemical composition and nutritive value of grain sorghum. J. Sci. Food Agric. 28: 963970.**

**Paramahans, S.V. & Taranathan, R.N. 1980. Carbohydrate composition of millet varugu.**

**Staeke, 32: 73-76**

**Patel, T.B., Boman, T.J. & Dalal, U.C. 1958. An epidemic of ergot poisoning through ingestion of infected bajri (Pennisetum typhoideum) in southern parts of Bombay State. Indian J. Med. Sci., 12: 257-261.**

**Pattabiraman, T.N. 1985. Trypsin/chymotrypsin inhibitors from millets. Adv. Exp. Med. Biol. 199: 439-448.**

**Patwardhan, V.N. 1961a. Nutrition in India. Bombay, Indian Journal of Medical Sciences. 2e d. 515 p.**

**Patwardhan, V.N. 1961 b. Nutritive value of cereal and pulse proteins. In Progress in meeting protein needs of infants and preschool children p. 201-210. Publication No. 843. Washington, DC, National Academy of Sciences, National Research Council.**

**Pedersen, B. & Eggum, B.0. 1983. The influence of milling on the nutritive value of flour from cereal grains. 6. Sorghum. Qual Plant. Plant Foods Hum. Nutr., 33: 313-326.**

**Perten, H. 1972. Camposite flour studies in Senegal. Presented at a meeting on the production and marketing of composite flour bakery products and pasta goods, Bogota, Colombie, octobre.**

**Perten, H. 1977. Specific characteristics of millet and sorghum milling. In D.A.V. Dendy, d. Proceedings of a symposium on sorghum and millets for human food, Vienne, 11 12 mai 1976, p. 47-51. Londres, Institut des produits tropicaux.**

**Perten, H. 1983. Practical experience in processing and use of millet and sorghum in Senegal and Sudan. Cereal Foods World 28: 680-683.**

**Pore, M.S. & Magar, N.G. 1977. Nutritive value of hybrid varieties of finger millet. Indian J. Agric. Sci. 47: 220-228.**

**Price, M.L. & Butler, L.G. 1979. Treatments of sorghum grain that reduce the assayable tannin content and their effect on the nutritional value of the grain. In J.H. Hulse, d. Pa/vphenals in cereals and legumes p. 39-42. Ottawa, Canada, Centre de recherche pour le dveloppement international.**

**Price, M.L., Hagerman, A.E. & Butler, L.G. 1980. Tannin in sorghum grain: effect of cooking on chemical assays and on antinutritional properties in rats. Nutr. Rep. Int. 21: 761 -767.**

**Price, P.B. & Parson, J.G. 1975. Lipids of seven cereal grains. J. Am. Oil Chem. Sac . 52: 490-493.**

**Purseglove, J.W. 1972. Trapical crops: monocotyledons, Vol. 1. Londres, Longman Group**

**Limited. 334 p.**

**Pushpamma, P. 1990. Importance of sorghum as food in Asia. In G. Ejeta, E.T. Mertz, L.W. Rooney, R. Schaffert & J. Yohe, ds. Proceedings of the International Conference an Sorghum Nutritional Qualitv. 26 fvrier - 1er mars 1990, p.229-241. West Lafayette, Indiana, Etats-Unis, Purdue University.**

**Pushpamma, P. & Chittemma Rao, K. 1981. Varietal preference marketing, .storage, processing and utilization of sorghum and millets in Andhra Pradesh. Hyderabad, Inde, College of Home Science. Andhra Pradesh Agricultural University.**

**Pushpamma, P., Chittemma Rao, K., Sudhakar Reddy, K. & Prameela, D. 1985. Storage of sorghum and millets at domestic level in Andhra Pradesh, India. Bull. Grain Technol., 23: 50-60.**

**Pushpamma, S., Parrish, D.B. & Deyoe, C.W. 1972. Improving protein quality of millet, sorghum and maize diets by supplementation. Nutr. Rep. Int. 5: 93100.**

**Radhakrishnan, M.R. & Sivaprasad, J. 1980. Tannin content of sorghum varieties and their role in iron bioavailability.J. Agric. Food Chem 28: 55-57.**

**Rajalakshmi, R. & Mujumdar, N. 1966. Effect of different legume supplements on the**

**nutritive value of maize and jowar to albino rats. Baroda J. Nutr.: 2: 2130.**

**Ramachandra, G., Virupaksha, T.K. & Shadaksharaswamy, M. 1977. Relationship between tannin levels and in vitro protein digestibility in finger millet (Eleusine caracana Gaertn.). J. Agric. Food Chem.. 25: 1101 - 1104.**

**Rao, A. & Vimala, V. 1993. Efficacy of tricalcium phosphate on the storage quality of sorghum flour. .1. Food Sci. Technol., 30: 58-59.**

**Rao, H. & Shurpalekar, S.R. 1976. Utilization of milo in bakery products. J. Food Sci. Technol. 13: 293-299.**

**Rao, S.A. & Mushonga, J.N. 1985. Traditional food crops in Zimbabwe. l. Finger millet. Zimbabuwe Agric. J., 82: 101-104.**

**Reardon, T. 1993. Cereals demand in the Sahel and potential impacts of regional cereals production. World Dev. 21: 17-35.**

**Reardon, T. & Matlon, P. 1989. Seasonal food insecurity and vulnerability in droughtaffected regions of Burkina Faso. In D. E. Sahn , d. Seasonal variability in third world agriculture. The consequene es for food security p. 118- 136. Baltimore, Maryland, Etats-Unis, International Food Policy Research Institute, Johns Hopkins University.**

**Reichert, R.D., Mwasaru, M.A. & Mukuru, S.Z. 1988. Characterization of colouredgrain sorghum lines and identification of high-tannin lines with good dehulling characteristics. Cereal Chem. 65: 165- 170.**

**Reichert, R.D. & Youngs, C.G. 1977. Dehulling cereal grains and grain legumes for developing countries. ll. Chemical composition of mechanically and traditionally dehulled sorghum and millet. Cereal Chem. 54: 174-178.**

**Ring, S.H., Akingbala, J.O. & Rooney, L.W. 1982. Variation in amylose content among sorghums. In L.W. Rooney & D.S. Murty, ds. Proceedings of the International Symposium on Sorghum Grain Qua/ity Hyderabad, Inde, 28-3 1 octobre 1981, p. 269-279. Patancheru, Inde, ICRISAT.**

**Rizley, N.F. & Suter, D.A. 1977. Sorghum tortillas: process and product attributes. J. Food Sci. 42: 1435-1438.**

**Rohrbach, D.D. 1991. Marketing constraints and opportuniyies for sorghum and millet in southern and eastern Africa. Economics Group, Resource Management Programme, Progress Report 106. Patancheru, Inde, ICRISAT.**

**Rooney, L.W. 1978. Sorghum and pearl millet lipids. Cereal Chem. 55: 584-590.**

**Rooney, L.W. 1992. Wet milling nixtamalization and micronization of sorghum. In M.I. Gomez. L.R. House, L.W. Rooney & D.A.V. Dendy, ds. Utilization of sorghum and millets p. 19-21. Patancheru, Inde, ICRISAT.**

**Rooney, L.W., Kirleis, A.W. & Murty, D.S. 1986. Traditional foods from sorghum: their production, evaluation and nutritional value. Adv. Cereal Sci. Technol.. 8: 317-353.**

**Rooney, L.W. & McDonough, C.M.1987. Food quality and consumer acceptance of pearl millet. Proceedings of the International Pearl Millet Workshop Hyderabad, Inde, 7-11 avril 1986, p. 43-61. Patancheru, Inde, ICRISAT.**

**Rooney, L.W. & Serna-Saldivar, S.0. 1991. Sorghum. In K.J. Lorenz & K. Kulp, ds. Handbook of cereal science and technology p. 233-269. New York, Marcel Dekker.**

**Rostango, H.S. 1972. Nutritive evaluation of sorghum grains in C hicks. Thse de doctorat. Purdue University, West Lafayette, Indiana, Etats-Unis.**

**Saito, M. & Ohtsubo, K. 1974. Trichothecene toxins of fusarium species. In I.F.H. Purchase, d. Mycotoxins, p. 263-281. Amsterdam, Elsevier.**

**Salunkhe, D.K., Chavan, J.K. & Kadam, S.S. 1990. Dietary tannins: consequences and remedies.. Boca Raton, Floride, Etats-Unis, CRC Press.**

**Salunkhe, D.K., Jadhav, S.J., Kadam S.S. & Chavan, J.K. 1982. Chemical, biochemical and biological significance of polyphenols in cereals and legumes. CRC Crit. Rev. Food Sci. Nutr.. 17: 277-305.**

**Sankara Rao, D.S. & Deosthale, Y.G. 1980. Effect of pearling on mineral and trace element composition and ionizable iron content of sorghum. Nutr. Rep. Int., 22: 723728**

**Sankara Rao, D.S. & Deosthale, Y.G. 1983. Mineral composition, ionizable iron and soluble zinc in malted grains of pearl millet and ragi. Food Chem 11: 217223.**

**Satyanarayana, U., Raju, R.V.S., Deosthale, Y.G. & Rao, C.N. 1988. Trace metals in urinary calculus disease. Abstract C41. Presented at the 4th Asian-Pacific Congress of Clinical Biochemistry, Hong Kong, 28 aot - 2 septembre.**

**Sauer, D.B. 1988. Mold invasion in relation to grain damage. Cereal Foods World 33: 489-490.**

**Sawaya, W.N., Khalil, J.K. & Safi, W.J. 1984. Nutritional quality of pearl millet flour and bread. Qual. Plant. Plant Foods Hum. Nutr., 34: 117- 125.**

**Sawhney, S.K. & Naik, M.S. 1969. Amino acid composition of protein fractions of pearl millet and the effect of nitrogen fertilization on its proteins. Indian J. Genet. Plant Breed.**

29: 395-406.

Scheuring, J.F., Sidibe, S., Rooney, L.W. & Earp, C.F. 1983. Sorghum pericarp thickness and its relation to decortication in a wooden mortar and pestle. Cereal Chem. 60: 86-89.

Seenappa, M. 1988. Sorghum and millets in East Africa with reference to their use in weaning foods. In D. Alnwick, S. Moses & O.G. Schmidt, ds. Improring young child feeding in eastern and southern Africa p. 39-54. Nairobi, Kenya, Centre de recherche pour le dveloppement international.

Seetharam, A., Riley, K.W. & Harinarayana, G. 1989. Small millets in global agriculture. New Delhi, Inde, Oxford and IBH. 392 p.

Serna-Saldivar, S.D., McDonough, C.M. & Rooney, L.W. 1991. The millets. In K.J. Lorenz & K. Kulp, ds. Handbook of cereal science and technology p. 271 300. New York, Marcel Dekker.

Shah, H.C & Mehta, B.V. 1959. Comparative studies on the effect of ammonium chloride and other fertilizers on the yield and crude protein content of pearl millet. Indian J. Agron. 4: 105-113.

Sheorain, V.S. & Wagle, D.S. 1973. Beta-amylase activity in germinated bajra and barley varieties. J. Food Sci. Technol., 10: 184-186.

**Sherrod, L.B., Albin, R.C. & Furr, R.D. 1969. Net energy of regular and waxy sorghum grains for finishing steers. J. Anim. Sci., 29: 997- 1000.**

**Shivaraj, B. & Pattabiraman, T.N. 1981. Natural plant enzyme inhibitors: characterization of an unusual a-amylase/trypsin inhibitor from ragi (Eleusine coracana Gaertn.). Biochem. J., 193: 29-36.**

**Shotwell, O.L., Hesseltine, C.W., Burmelster, H.R., Kwolek, W.F., Shannon, &.M. & Hall, H.H. 1969. Survey of cereal grains and soybeans for the presence of aflatoxin: 1. Wheat, grain sorghum, and oats. Cereal Chem ., 46: 446-454.**

**Shrestha, K.B. 1972. Dehusking of varagu and its ulilization for edible purposes. Thse de matrise. University of Mysore, Karnataka, Inde.**

**Shukla, S.S., Gupta, O.P., Sharma, Y.K. & Sawarkar, N.S. 1986. Puffing quality characteristics of some ragi (Eleusinc coracana) cultivars. J. Food Sci. Techno/., 23: 329330.**

**Siddiqui, A.H. 1955. Fluorosis in Nalagonda district, Hyderabad-Deccan. Br Med. J.,2: 1402-1410.**

**Sikabbubba, R.M. 1989. The effect of alcohol soluble proteins an the digestibility of sorghum Thse de matrise. Kansas State University, Manhattan, Kansas, Etats-Unis.**

**Silano, V. 1977. Factors affecting digestibility and availability of protein in cereals. In Nutritional evaluation of cereal mutants. Proceedings of the Advisory Group Meeting on a Nutritional Evaluation of Cereal Mutants, p. 13-46. Vienne, Agence internationale de l'nergie atomique.**

**Simwemba, C.G., Hoseney, R.C., Varriano-Marston, E. & Zeleznak, K. 1984. Certain B vitamin and phytic acid contents of pearl millet [Pennisetum americanum (l.) Leeke]. J. Agric . Food Chem. 32: 31 -34.**

**Singh, P., Singh, U., Eggum, B.O., Kumar, K.A. & Andrews, D.J. 1987. Nutritional evaluation of high protein genotypes of pearl millet (Pennisetum americanum (L.) Leeke). J. Sci. Food Agric., 38: 41 -48.**

**Singh, R. & Axtell, J.D. 1973a. High lysine mutant gene (hl) that improves protein quality and biological value of grain sorghum. Crop Sci. 13: 535-539.**

**Singh, R. & Axtell, J.D. 1973b. Survey of world sorghum collection for opaque and sugary lines. In Inheitance and improvement of protein quality and content in sorghum , No. 10 Research Progress Report No. 10, p. l-18. Lafayette, Indiana, Etats-Unis, Department of Agronomy, Agricultural Experiment Station Purdue University; Washington DC, Etats-Unis, Agence pour le dveloppement international.**

**Singh, R. & Popli, S. 1973. Amylose content and amylolytic studies on high-yielding varieties of bajra (Pennisetum typhoides). J. Food Sci. Technol. 10: 31-33.**

**Singleton, V.L. & Kratzer, F.H. 1973. Plant phenolics. In Toxicants p. 309-345. Washington, DC, National Research Council, National Academy of Sciences.**

**Snowden, J.D. 1936. The cultivated races of sorghum Londres, Adlard and Son. 274 p.**

**Sood, S. & Kapoor, A.C. 1992. Effect of storage and insect infestation on protein and starch digestibility of cereal grains. Food Chem. 44: 209-212.**

**Southgate, D.A.T., Hudson, G.J. & Englyst, H. 1978. The analysis of dietary fibre - the choices for the analyst. J. Sci. Food Agric . 29: 979-988.**

**Srikantia, S.G., Narasinga Rao, B.S., Raghuramulu, N. & Gopalan, C. 1968. Pattern of nicotinamide nucleotides in the erythrocytes of pellagrins. Am.J. Clin. Nut,:, 21: 1306-1309.**

**Steinkraus, K.H. 1983. Handbook of indigenous fermented foods. New York, Marcel Dekker.**

**Stemler, A.B.L., Collius, F.l., de Wet, l.M.J. & Harlan, J.R. 1976. Variation in levels of lipid composition and protein in econogeographic races of Sorghum bicolor. Biochem. Syst. Ecol.**

**4: 43-45.**

**Stuart, M.A., Johnson, P.E., Hamaker, B.E. & Kirleis, A. 1987. Absorption of zinc and iron by rats fed meals containing sorghum food products. J. Cereal Sci. 6: 81-90.**

**Subrahmanyan, V., Narayana Rao, M., Rama Rao, G. & Swaminathan, M. 1955. The metabolism of nitrogen. calcium, and phosphorus in human adults on a poor vegetarian diet containing ragi (Eleusine coracana). Br. J. Nutr., 9: 350357.**

**Subramanian, V., Butler, L.G., Jambunathan, R. & Prasad Rao, K.E. 1983. Some agronomic and biochemical characters of brown sorghums and their possible role in bird resistance. J. Agric. Food Chem. 31: 1303-1307.**

**Subramanian, V. & Jambunathan, R. 1980. Traditional methods of processing sorghum (Sorghum bicolor L. Moench) and pearl millet (Pennisetum americanum L.) grains in India. Rep. Int. Assoc . Cereal Chem., 10: 115-118.**

**Subramanian, V. & Jambunathan, R. 1 982. Properties of sorghum grain and their relationship to roti quality. In L.W. Rooney & D.S. Murty, eds. Proceedings at the International Symposium on Sorghum Grain Quality Hyderabad, Inde, 2831 octobre 1981, p. 280-288. Patancheru, Inde, ICRISAT.**

**Subramanian, V., Jambunathan, R. & Ramaiah, C.D. 1986. Physical and chemical characteristics of pearl millet grains and their relationship to roti quality. J. Food Sci. 51: 1005-1020.**

**Subramanian, V., Jambunathan, R. & Suryaprakash, S. 1980. Note on the soluble sugars of sorghum. Cereal Chem. 57: 440-441.**

**Subramanian, V., Jambunathan, R. & Suryaprakash, S. 1981. Sugars of pearl millet [Pennisetum americanum (L.) Leeke] grains. J. Food Sci., 46: 1614-1615.**

**Subramanian, V., Murty, D.S., Jambunathan, R. & House, L.R. 1982. Boiled sorghum characteristics and their relationship to starch properties. In L.W. Rooney & D.S. Murty, ds. Proceedings of the International Symposium an Sorghum Grain Quality Hyderabad, Inde, 28-31 octobre 1981, p. 103-109. Patancheru, Inde, ICRISAT.**

**Sullins, R.D. & Rooney, L.W. 1977. Pericarp and endosperm structure of pearl millet (Pennisetum typhoides). In D.A.V. Dendy, d. Proceedings of a sympo sium on sorghum and millets for human food Vienne, 11 -12 mai 1976 p. 79. Londres, Institut des produits tropicaux.**

**Suryanarayana Rao, K., Rukmini, C. & Mohan, V.S. 1968.13-carotene content of some yellow-endospenn varieties of sorghum. Indian J. Agric . Sci. 38: 368372.**

**Tanner, F.W. Jr, Pfeiffer, S.E. & Curtis, J.J. 1947. B-complex vitamins in grain sorghums. Cereal Chem. 24: 268-274.**

**Tashiro, M. & Maki, Z. 1977. An evaluation of the nutritive value of proso-millet protein [rsum en anglais]. Kyoto Furitsu Daigaku Gakujutsu Hokoku: Rigaku. Seikatsu Kagaku, 28: 23-30.**

**Taur, A.T., Pawar, V.D. & Ingle, U.M. 1984. Effect of fermentation on nutritional improvement of grain sorghum (Sorghum bicolor (L.) Moench). Indian J. Nutr. Diet., 21: 129-136.**

**Teeter, R.G., Sarani, S., Smith, M.O. & Hibberd, C.A. 1986. Metabolism and nutrition. Detoxification of high-tannin sorghum grains. Poult. Sci., 65: 67-71.**

**Thiam, A.A. 1981 . Contribution of ITA to the development of composite flours. Paper presented at the Regional Workshop on Composite Flours for Industrial Processing of Sorghum for Bakery and Allied Food Industries in Africa, Institute of Tropical Agriculture, Khartoum, Soudan, 7- 12 dcembre.**

**Thiam, A.A. & Ndoye, A. 1977. Bread from millet. League Int. Food Educ. Newsl. August.**

**Thorat, S.S., Satwadhar, P.N., Kulkarni, D.N., Choudhari, S.D. & Ingle, U.M. 1988. Et`fect of**

**various grain parameters on popping quality of sorghum. J. Food Sci. Technol. 25: 361 -363.**

**Tipton, K.W., Floyd, E.M., Marshall, J.G. & McDevitt, J.B. 1970. Resistance of certain grain sorghum hybrids to bird damage in Louisiana. Agron. J., 62: 211 213.**

**Tomita, Y., Sugimoto, Y., Sakamoto, S. & Fuwa, H. 198 1. Some properties of starches of grain amaranth and several millets. J. Nutr. Sci. Vitaminol., 27: 471 484.**

**Tomkins, A., Alnwick, D. & Haggerty, P. 1988. Fermented foods for improving child feeding in eastern and southern Africa: a review. In D. Alnwick, S. Moses & O.G. Schmidt, ds. Improving child feeding in eastern and southern Africa p. 136-167. Nairobi, Kenya, Centre de recherche pour le dveloppement international.**

**Tripathi, R.K. 1973. Aflatoxins in sorghum grains infected with head moulds. Indian J. Exp. Biol. 11: 361-362.**

**Trowell, H. 1976. Definition of dietary fiber and hypothesis that it is a protective factor in certain diseases. Am. J. Clin. Nutr. 29: 417-427.**

**Udayasekhara Rao, P. & Deosthale, Y.G. 1988. In vitro availability of iron and zinc in white and coloured ragi (Eleusine coracana): role of tannin and phytate. Plant Foods Hum. Nutr., 38: 35-41.**

**Underwood, E.J.. 1971.Trace elements in human and animal nutrition. New York, Academic Press. 3e d. 543 p.**

**United States Department of Agriculture/Human Nutrition Information Service (USDA/HNIS). 1984. Composition of foods: cereal grains and pasta. Agriculture Handbook No. 8-20. Washington, DC.**

**United States National Research Council/National Academy of Sciences. 1982. United StatesCanadian tables of fred composition. Washington, DC, National Academy Press. 3e rev. van Heerden, I.V. 1989. The nutritive content of African beers brewed with maize grits or sorghum adjuncts. J. Inst. Brew., 95: 17-20. van Heerden, I.V. & Glennie, C.W. 1987. Availability of B vitamins in sorghum beer. Nutr Rep. Int. 35: 147- 155. van Heerden, I.V., Taylor, J.R.N. & Glennie, C.W. 1987. The contribution of minerals, trace elements, phytin starch and amino acids to the nutritional quality of sorghum beer. S. Afr. .l. Sci., 83: 5-7.**

**Van Scoyoc, S.W., Ejeta, G. & Axtell, J.D. 1988. Kernel characteristics and protein traction changes during seed development of high-lysine and normal sorghums. Cereal Chem., 65: 75-80.**

**Vimala, V., Kaur, K.J. & Hymavati, T.V. 1990. Processing of millets - scope for diversification. Proceedings of the Summer Institute on Appropriate Food Processing Technologies for Rural Development 15 juin - 4 juillet 1990, p. 3952. Hyderabad, Inde,**

**Andhra Pradesh Agricultural University.**

**Virupaksha, T.K., Ramachandra, G. & Nagaraju, D. 1975. Seed proteins of finger millet and their amino acid composition. J. Sci. Food Agric . 26: 1237 1246.**

**Virupaksha, T.K. & Sastry, L.V.S. 1968. Studies on the protein content and amino acid composition of some varieties of grain sorghum. J. Agric . Food Chem., 16: 199-203.**

**Vogel, S. & Graham, M., ds. l 979. Sorghum and millet: food production and use. Report of a workshop, Nairobi, Kenya, 4-7 juillet 1978. Ottawa, Canada, Centre de recherche pour le dveloppement international.**

**Waggle, D.H. & Deyoe, C.W. 1966. Relationship between protein level and amino acid composition of sorghum grain. Feedstuffs 38: 1819.**

**Waggle, D.H., Deyoe, C.W. & Smith, F.W. 1967. Effect of nitrogen fertilization on the amino acid composition and distribution in sorghum grain. Crop Sci., 7: 367-368.**

**Walker, T.S. 1990. Demand and supply prospects far sorghum: implication for crop improvement strategv\y. Presented at the 20th Annual Sorghum Workshop, Mahatma Phule Agricultural University, Rahuri, Inde, 30 avril - 2 mai.**

**Wall,.l.S. & Carpenter, K.,1. 1988. Variation in availability of niacin in grain products. Food**

**Technol. (Chicago), 42(10): 198-204.**

**Wang, C., Mitchell, H.C. & Barham, H.N. 1959. The phytin content of sorghum grain. Trans. Kans. Acad. Sci. 62: 208-211.**

**Wang, Y.D. & Fields, M.L. 1978. Germination of corn and sorghum in the home to improve nutritive value. J. Food Sci. 43: 1113- 1115.**

**Wankhede, D.B., Shehnaj, A. & Raghavendra Rao, M.R. 1979a. Carbohydrate composition of finger millet (Eleusine coracana) and foxtail millet (Seturia italica). Qual. Plant. Plant Foods Hum. Nutr., 28: 293-303.**

**Wankhede, D.B., Shehnaj, A. & Raghavendra Rao, M.R. 1979b. Preparation and physicochemical properties of starches and their fractions from finger millet (Eleusine coracana) and foxtail millet (Setaria italica). Starch 31: 153.**

**Warsi, A.S. & Wright, B.C. 1973. Effects of rates and methods of nitrogen application on the quality of sorghum grain. Indian J. Agric. Sci., 43: 722-726.**

**Watterson, J.J. & Butler, L.G. 1983. Occurrence of an unusual leucoanthocyanidin and absence of proanthocyanidins in sorghum leaves. J. Agric . Food Chem.. 31: 41-45.**

**Whistler, R.L. & Paschall, E.F., ds. l 967. Starch chemistry and technology, Vol. 2, Industrial**

**aspects. New York et Londres, Academic Press.**

**Whitaker, M.E. & Tanner, M. 1989. Methods of determining the bioavailability of amino acids for poultry. In M. Friedman, d. Absorption and utilization of amino acids, Vol. 3, p. 129-141. Boca Raton, Floride, Etats-Unis, CRC Press.**

**Yanez, G.A. & Walker, C.E. I 986. Effect of tempering parameters on extraction and ash of proso millet flours, and partial characterization of proso starch. Cereal Chem., 63: 164-167.**

**Youssef, M.M.A., Moharram, Y.G., Moustaffa, H., Bolling, H., El-Baya, A. & Harmuth, A.E. 1990. New extruded products from sorghum. Food Chem., 37: 189199.**

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