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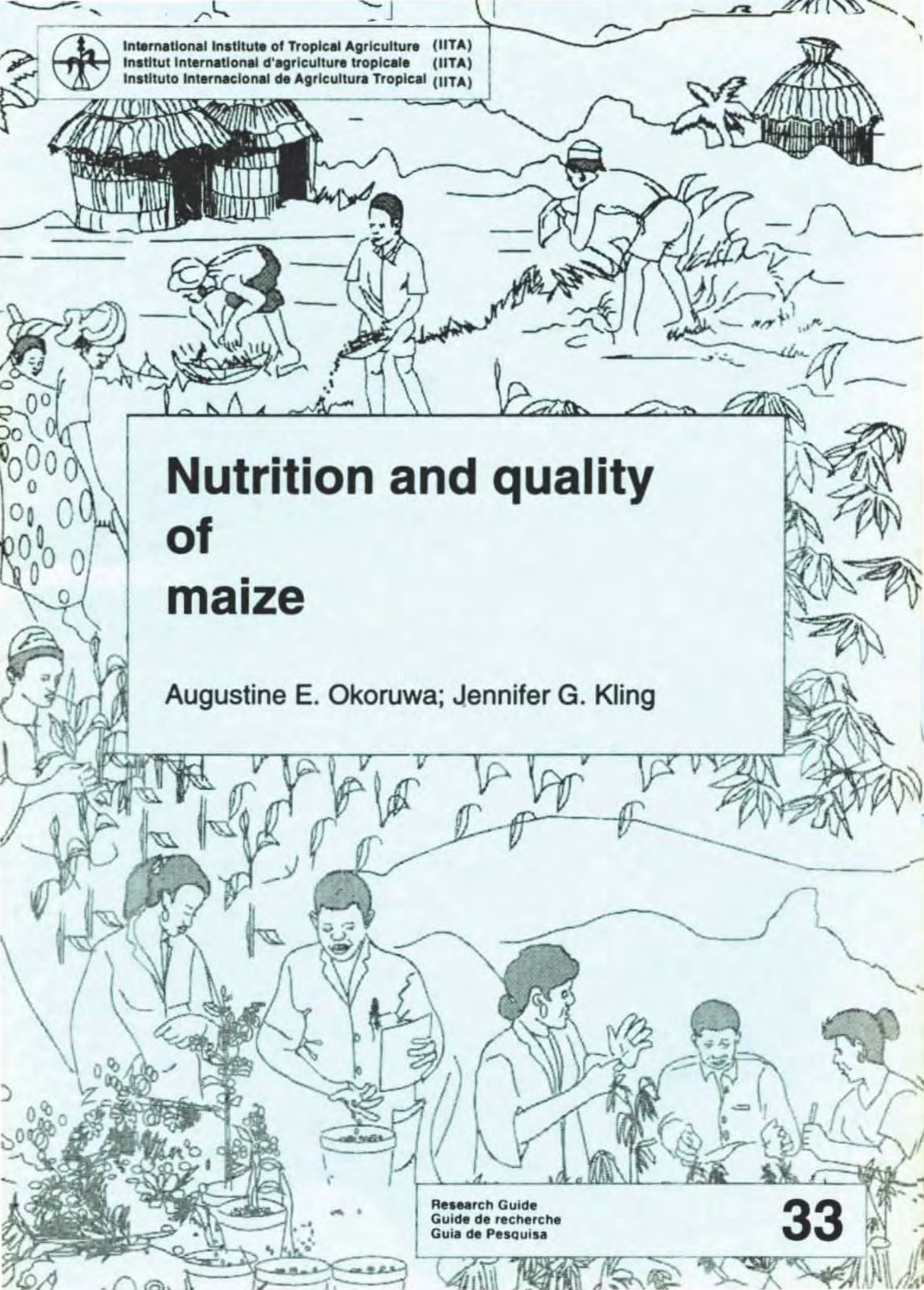

Nutrition and quality of maize

Augustine E. Okoruwa; Jennifer G. Kling

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IITA Research Guide 33

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Nutrition and quality of maize

Objectives. This guide is intended to enable you to:

- discuss the importance of maize in human nutrition;
- explain the value of maize as source of essential nutrients;
- describe the nutritional components of maize;
- explain the effect of mycotoxins;
- describe methods for measuring quality;
- describe quality requirements for specific end-uses.

Study materials

- Transparencies with nutritional data of maize.
- Maize varieties with different physical and chemical properties.
- Slides showing nutritional diseases.
- Illustrations of kernels showing differences in endosperm type.
- Charts/tables showing nutritional composition of African foods.

Practicals

- Determine the nutritional value of a typical diet in your country and compare to recommended allowances.
- Detect the presence of mycotoxins.
- Measure quality characteristics.

Questions

1 Why is quality of maize important in Africa?
2 When does the human body use protein as an alternative source of energy?
3 Why is it important to consume both the essential amount and the type of protein that we need daily?
4 What two nutritional diseases are associated with inadequate consumption of calories and proteins?
5 What are the parts of a maize kernel?
6 How are varieties classified according to endosperm consistence?
7 What does "net utilization" of proteins mean?
8 What type of maize provides substantial amounts of vitamin A?
9 What factors affect the value of maize dishes?
10 What nutrients tend to be low in all cereals?
11 In what nutrients is maize particularly low?
12 How much maize would a man of 70 kg have to consume per day to meet his energy requirements?
13 Why is it essential to complement maize with other food?
14 What essential amino acids are deficient in maize and other cereals?
15 Why is consumption of maize with a legume a means of improving protein quality in the diet?
16 What are the advantages and disadvantages of Quality Protein Maize (QPM) varieties?
17 What is the cause of pellagra disease?
18 Why is maize oil of good quality?
19 What is the effect of mycotoxins in maize?
20 What are some of the most important characteristics affecting grain quality?
21 What is the effect of genotype and environment interaction on maize quality?
22 Why is maize preferred as a feed source?

Nutrition and quality of maize

1 Maize in human nutrition
2 Maize as source of essential nutrients
3 Nutrition of maize-based diets
4 Mycotoxins
5 Measuring quality
6 Maize quality for specific end-uses
7 Bibliography
8 Suggestions for trainers

Abstract. Maize is a major cereal crop. Worldwide, wheat, maize, and rice are produced in greater quantities than any other crop. Of these crops, maize has the highest average yield per hectare. Maize is a good source of energy for both humans and animals. It is high-yielding, easy to process and readily digested. Maize is deficient in lysine and tryptophan, however, consumption with a legume improves protein quality in the diet. The oil is of good quality. Varieties differ in physical and chemical properties of the grain, which affects their suitability for various end uses.

1 Maize in human nutrition

Maize and other cereal grains constitute important sources of carbohydrates, proteins, vitamin B, and minerals. In some regions, maize serves as the primary staple while in other regions, maize is combined with other cereal grains.

In Africa, where maize is mostly used for human consumption, dietary preferences, processing and mode of preparation affect the contributions of maize in human nutrition. Nutritional factors, although important in determining quality, are often overlooked since no premium is given in the market for maize varieties with superior nutritional value.

Human beings require certain nutrients in their diet for good health. Since animals cannot produce energy through photosynthesis, or take up nutrients from the soil, they must rely ultimately on plant sources to provide essential nutrients. The minimum requirements must be met for six groups of nutrients:

- carbohydrates,
- fats and oils,
- protein,
- vitamins,
- minerals,
- water.

Digestion of carbohydrates, fats, and proteins provide energy needs. The body stores energy in fats, which can be utilized when calorie intake is insufficient to meet demand. If fat reserves are depleted, the body may use protein as an alternative source of energy. This may be detrimental to health since proteins are required for tissue maintenance and repair, as well as for many enzymatic processes in the body.

The body does not have the capacity to store proteins and most vitamins in the same way that it stores energy in fat tissue. It is important to consume both the essential amount and the type of protein that we need daily.

Two nutritional diseases associated with inadequate consumption of calories and/or protein are:

- marasmus,
- kwashiorkor.

Marasmus. Marasmus results from an inadequate intake of calories in the diet. A person suffering from marasmus is emaciated, reduced to skin and bones.

Kwashiorkor. Kwashiorkor occurs when calorie intake is sufficient but protein intake is deficient. Kwashiorkor occurs in young children who are fed largely on food high in carbohydrates at a time when their requirement for protein is relatively large. Kwashiorkor is exercebated by high levels of aflatoxin in the diet. African children suffering from this disease usually have swollen stomachs and sometimes have reddish hair.

Table 1 gives recommendations for daily intake of eight important nutrients for various age groups.

Table 1. Recommended daily intake of eight major nutrients (for moderate workload; WHO).

	Age group	Energy kcal	Protein mg	Calcium mg	Iron mg	Vit. A* mg	Thiamine mg	Riboflavin mg	Niacin mg	Vit. C mg
Children	1	820	14	500-600	5-10	18	0.3	0.5	5.4	20
	1-2	1150	14	400-500	5-10	15	0.5	0.8	9.0	20
	2-3	1350	16	400-500	5-10	15	0.5	0.8	9.0	20
	3-5	1550	18	400-500	5-10	18	0.7	1.1	11.7	20
Boys	5-7	1850	21	400-500	5-10	18	0.7	1.1	12.1	20
	7-10	2100	27	400-500	5-10	24	0.9	1.3	14.5	20
	10-12	2200	34	600-700	5-10	35	1.0	1.6	17.2	20
	12-14	2400	43	600-700	8-16	44	1.2	1.7	19.0	28
	14-16	2650	52	600-700	8-16	45	1.2	1.8	19.8	30
	16-18	2850	56	500-600	5-9	45	1.2	1.8	20.3	30
Girls	5-7	1750	21	400-500	5-10	18	0.7	1.1	12.1	20
	7-10	1800	27	400-500	5-10	24	0.9	1.3	14.5	20
	10-12	1950	36	600-700	5-10	35	0.9	1.4	15.5	20
	12-14	2100	44	600-700	10-20	44	1.0	1.5	16.4	28
	14-16	2150	46	600-700	13-26	45	1.0	1.5	16.4	30
	16-18	2150	42	500-600	14-28	45	0.9	1.4	15.2	30
Men	18-30	3000	49	400-500	5-9	45	1.2	1.8	19.8	30
	30-60	2900	49	400-500	5-9	45	1.2	1.8	19.8	30
	> 60	2450	49	400-500	5-9	45	1.2	1.8	19.8	30
Women	18-30	2100	41	400-500	14-28	45	0.9	1.3	14.5	30
	30-60	2150	41	400-500	14-28	45	0.9	1.3	14.5	30
	> 60	1950	41	400-500	14-28	45	0.9	1.3	14.5	30
Pregnancy (last 3 months)		+ 285	+ 6	1000-1200	14-28	45	+0.1	+0.2	+2.3	30
Lactation (first 6 months)		+ 500	+ 17.5	1000-1200	14-28	72	+0.2	+0.4	+3.7	30

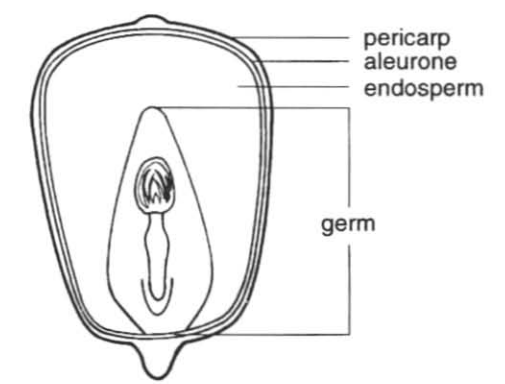
* mg beta-carotene or equivalent. 1 mg beta-carotene = 1.67 IU (international units) vitamin A.

2 Maize as source of essential nutrients

The maize kernel is made up of endosperm (83 % of total dry weight), germ (11 %), pericarp (5 %) and tip cap (pedicel; 1 %) (Figure 1). Table 2 shows the composition of each kernel part.

The endosperm consists of starch granules embedded in a protein matrix. Flinty endosperm has a more rigid protein structure and is also higher in protein content than floury endosperm. Floury granules are also surrounded by a protein matrix, but the matrix is thinner and tends to rupture upon drying, leaving air pockets. With further drying, floury endosperm shrinks to some extent.

Figure 1. Maize kernel.



	Starch	Protein	Oil	Sugar	Ash	Others
Whole grain	73.4	9.1	4.4	1.9	1.4	9.8
Endosperm	87.6	8.0	0.8	0.6	0.3	2.7
Germ	8.3	18.4	33.2	10.8	10.5	8.8
Pericarp	7.3	3.7	1.0	0.3	0.8	86.9
Tip cap	5.3	9.1	3.8	1.6	1.6	78.6

Table 2. Composition of components of dent maize kernel (% dry basis).

The distribution of flinty and floury endosperm determines whether a variety is classified as flint, floury, or dent (Figure 2). Shrinking of the central core of floury endosperm in dent varieties is responsible for the dent at the top of the kernel.

Protein concentration is higher in the germ than in the endosperm. The protein in the germ is of a better quality than protein from the endosperm. However, since the endosperm portion is greater, the majority of protein in the kernel is in the endosperm (Table 3). The germ contributes most of the oil, sugar, and ash (including vitamins and minerals).

Maize as an energy source compares favorably with root and tuber crops and is similar in energy value to dried legumes (Table 4). The protein content of cereals is considerably higher than root and tuber crops, but only about half as high as the protein content of dried legumes. Cereals are important contributors of iron and B vitamins (thiamin, riboflavin, and niacin) in the diet.

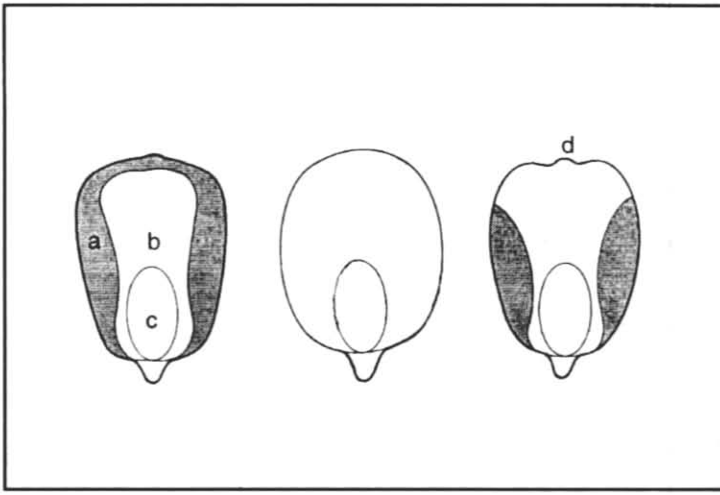


Figure 2. Flint, floury and dent maize varieties. (a = flint; b = floury endosperm; c = germ and d = dent).

Table 3. Proportion of constituents contained in specified fraction (% dry basis).

	Starch	Protein	Oil	Sugar	Ash	Others
Endosperm	98.0	72.3	15.4	28.9	17.9	26
Germ	1.4	24.2	82.5	69.1	78.2	12
Pericarp	0.5	2.6	1.3	1.2	2.9	54
Tip cap	0.1	0.9	0.8	0.8	1.0	7
Total	100.0	100.0	100.0	100.0	100.0	99.0

Table 4. Composition of common African food crops (per 100 g edible portion).

	Energy kcal	Protein %	Calcium mg	Iron mg	Vit. A* µg	Thiamine mg	Riboflavin mg	Niacin mg	Vit. C mg	H_2O %
Maize kernels (yellow maize)	353	10.4	13	4.9	125	.32	.12	1.7	4	10
Cassava (fresh)	138	1.2	68	1.9	45	.04	.05	0.6	31	62
Plantain (raw)	128	1.2	8	1.3	1170	.08	.04	0.6	20	65
Yam (fresh)	111	1.9	52	0.8	25	.11	.02	0.3	6	69
Cowpea (dried)	318	23.0	80	5.0	15	.90	.15	2.0	2	11
Soybean (dried)	407	34.0	185	6.1	83	.71	.25	2.0	0	11

(* ß-carotene or other pro-vitamin A (1 mg = 1 000 µg).

Of the three major cereals (wheat, maize, and rice), wheat has the highest concentration of protein in the grain (Table 5). The protein content of rice is relatively low, but the quality of the protein (balance of amino acids) is superior to both maize and wheat.

Table 5. Composition of cereals milled for human consumption (per 100 g).

	Protein %	Calcium mg	Iron mg	Vit. A* µg	Thiamin mg	Riboflavin mg	Niacin mg
Green maize, (Yellow maize, immature on cob, fresh)	5.0	18	1.8	360	.16	.08	1.3
Maize meal (White maize)	10.0	12	2.5	0	.35	.13	2.0
Maize flour (White maize)	8.0	6	1.1	0	.14	.05	1.0
Whole wheat flour	13.3	41	3.3	0	.55	.12	4.3
White wheat flour	10.5	16	0.8	0	.06	.05	0.9
Brown rice	7.5	39	2.0	0	.32	.05	4.6
White rice	7.6	24	0.8	0	.07	.03	1.6
Millet flour (finger)	5.6	315	54.0	25	.22	.10	0.8
Sorghum flour	9.5	28	10.0	20	.28	.09	3.4

* ß-carotene or other pro-vitamin A (1 mg = 1 000 µg).

The quality of a protein is reflected in the biological value obtained from experiments with growing rats (Table 6). "Net utilization" includes an additional adjustment for differences in digestibility of the protein.

Whole wheat flour and brown rice are better sources of calcium and niacin than whole maize, but much of these nutrients are lost when the bran and germ are removed (Table 5). Maize is a good source of vitamin B other than niacin and B_{12}.

Yellow maize can provide substantial amounts of Vitamin A in the diet. Vitamin A is not present to any great extent in white maize or other cereals. The maize germ is rich in Vitamin E.

Table 6. Biological ratings of cereal proteins for growing rats.

Protein source	Biological value %	Net utilization %
Whole egg	96	93
Whole maize	54	49
Whole wheat	67	61
White wheat flour	52	52
White rice	75	70
Maize germ	78	66
Wheat germ	75	71

3 Nutrition of maize-based diets

Several factors affect the nutritive value of maize dishes:

- variety of maize,
- production environment,
- condition of the grain,
- portion of the kernel used,
- method of processing/preparation,
- complementation with other foods.

The nutritive value of maize may increase or decrease depending on methods of preparation. Sprouting or fermentation of maize grains increases the digestibility as well as the content of some of the B vitamins. Sprouting increases the vitamin content (sprouting also increases the percentage of lysine in cereals while total protein is decreased). Milling reduces the concentration of proteins and lipids as well as fiber.

Maize is an excellent source of carbohydrates and good quality oil. It is more complete in nutrients in comparison to other cereals. All cereals tend to be low in lysine, tryptophan, and in available calcium. Maize is particularly low in niacin. Several factors contributing to the poor nutrition sometimes associated with people on maize-based diets include:

- low economic level,
- lack of knowledge about food nutrition and dietary requirements,
- faulty food habits,
- consumption of degraded low-quality grain.

A man weighing 70 kg for example, requires about 2 900 kcal to meet daily energy needs. This man would have to consume about 840 g of maize daily to meet his energy requirements, which is close to the actual per capita consumption in some maize-based diets.

Thus, maize is considered to be a good source of energy for both humans and animals. Maize is high-yielding, palatable, and readily digested. Maize is also relatively easy to process because the germ can be separated from the embryo more readily than in millet or sorghum. However, the oil in the germ can cause rancidity in maize products stored for a long time.

Diets that rely heavily on maize as an energy source may be deficient in certain amino acids (components of proteins) and vitamins. It is therefore essential to eat foods that complement the protein and vitamins present in maize to provide a well-balanced diet.

Protein quality. Maize and other cereal crops are deficient in two essential amino acids, lysine and tryptophan. However, the germ of the maize kernel has higher concentrations of these amino acids than the endosperm (Table 7). The germ also has a lower leucine to isoleucine ratio, giving it a higher biological value.

Maize preparations that include the germ have an improved protein composition, although the presence of oils in the germ reduces storability.

Proteins from legumes have higher concentrations of lysine and tryptophan, but are frequently deficient in methionine and cystine. Maize has adequate levels of these two amino acids. Consumption of maize with a legume is an effective means of improving protein quality in the diet.

Quality Protein Maize (QPM) varieties also improve protein quality in maize-based diets. QPM varieties have almost double the percentages of lysine and tryptophan compared to normal maize, but are similar in overall protein content. The major storage protein in maize, zein, is greatly reduced in QPM varieties, whereas the other protein fractions are increased. In general, amino acid compositions of the non-zein proteins are superior to zein proteins. Zein proteins are particularly deficient in lysine and tryptophan.

Compared to normal maize, production of QPM varieties may have disadvantages. QPM varieties have softer, floury endosperms, making them slightly lower yielding and more susceptible to storage insects. Although the breeding program at CIMMYT has successfully developed high-yielding, more flinty QPM varieties, they are still susceptible to weevils in storage.

Table 7. Amino acid composition (g) of normal maize endosperm and germ (per 100 g protein).

Amino acid	Endosperm	Germ
Lysine	2.0	6.1
Tryptophan	0.5	1.3
Leucine	14.3	6.5
Isoleucine	3.8	3.1
Arginine	3.8	9.1
Histidine	2.8	2.9
Phenylalanine	5.3	4.1
Methionine	2.8	1.7
Threonine	3.5	3.9
Valine	4.7	5.3

The opaque-2 mutation characteristic of QPM varieties is a recessive gene. Thus, contamination with pollen from normal maize can readily mask the presence of the gene. There is no easy method for identifying such outcrosses, so the benefits of QPM can be lost if proper isolation is not maintained.

Minerals and vitamins. The nutritional disease pellagra is sometimes associated with maize-based diets. The disease results from a deficiency of niacin. Much of the niacin present in maize is in a bound form (niacytin) which is not biologically available to monogastric animals. Furthermore, most of the niacin in the kernel (62.7 %) occurs in the aleurone layer (the outermost layer of the endosperm). This layer is often removed with the pericarp during dehulling.

Several methods of increasing niacin content in maize-based diets are:

- complement maize-based diets with groundnuts and fish which are rich in niacin.
- prepare maize in a way that retains the aleurone layer, contributing more niacin to the diet.
- cook maize in alkaline solution to increase niacin availability, a procedure commonly used in Latin America in the preparation of tortillas.

Pellagra seldom occurs among people who rely on maize as their staple food in Latin America. Table 8 gives the nutrient content of uncooked maize, masa (tortilla dough) and cooked tortilla.

Tortilla preparation slightly reduces the level of niacin in the maize product, but greatly increases the bio-availability of niacin.

An additional benefit in the preparation of tortillas is the large increase in calcium content from the lime. The calcium that is normally present in maize grain has low bio-availability because it forms complexes with phytin phosphorous. There may be slight decreases in the levels of lysine and tryptophan as a result of the lime treatment, however.

QPM varieties with high levels of the amino acid tryptophan may also compensate to some extent for the lack of available niacin in maize.

Table 8. Nutrient content during preparation of tortillas (mg/100 g dry weight).

	Uncooked maize	Masa	Tortilla
Calcium	9.00	190	190
Iron	2.70	3.60	3.70
Carotene	0.53	0.44	0.31
Thiamine	0.39	0.37	0.33
Riboflavin	0.09	0.10	0.10
Niacin	1.90	1.72	1.67

Oil quality. Maize oil can be extracted from germ separated during the industrial wet and dry milling processes. It is good quality oil both from a nutritional standpoint and in terms of cooking quality. It is rich in the essential polyunsaturated fatty acid linoleic acid, so that it remains a liquid at fairly low temperatures (Table 9). Palm oil, in contrast, is high in the saturated palmitic acid, giving it a higher melting temperature. Possibly, high levels of saturated fats in the diet are associated with increased risk of heart disease.

Maize oil is also low in linolenic acid and contains a high level of natural antioxidants, resulting in a stable oil with good flavor.

Table 9. Fatty acid structure and % composition of commercial vegetable oils.

	Structure*	Maize	Safflower	Soybean	Palm
Palmitic	16:0	11.0	4.6	10.7	44.0
Stearic	18:0	2.0	6.0	3.9	4.5
Oleic	18:1	24.1	7.3	22.8	39.2
Linoleic	18:2	61.9	79.0	50.8	10.1
Linolenic	18:3	0.7	0.1	6.8	0.4

*Number of carbon atoms: number of unsaturated bonds.

Although the quality of maize oil is good, the yield of oil is not as high as in some other crops. The industrial wet milling process is relatively complex and may not be feasible in many African countries. When oil is not a desired end-product, low oil content is often preferred for most processing methods and end-uses. Oil in flour or grits reduces storability and may interfere with further processing for example, in the industrial production of beer.

4 Mycotoxins

Mycotoxins are toxic substances produced by fungi. Aflatoxins are mycotoxins produced especially in stored agricultural crops by the fungus.

Aflatoxins are acutely toxic and carcinogenic causing poor development in livestock and in high doses, it is lethal. Aflatoxins exacerbate kwashiorkor in children and cause liver cancer in adults. The fungus infects the crop in the field and continues to spread in storage under high moisture and temperature. It is widespread in the tropics. Water stress during the growing season and insect damage during storage increase the likelihood of infection.

Some countries impose limits of 5-50 ppb of these toxins in commercial markets. The presence of the toxin can be detected using a "black box" in which maize is exposed to high intensity UV light. Maize fluoresces if the toxin is present.

Most countries have laboratories that can analyze the quantity of aflatoxins in a maize sample using thin layer chromatography or high power liquid chromatography.

Some methods of maize preparation such as roasting and treatment with alkali reduce levels of aflatoxin to some extent, but because of the acute toxicity of these compounds, processing alone does not provide sufficient protection. Gaseous ammonia can decrease aflatoxin levels by 99 %. This method is used industrially but may not be feasible for small-scale farmers, however. Some varieties appear to be more susceptible to *Aspergillus* spp. than others, but at present, no useful levels of resistance have been found in spite of much research.

Good cultural practices, proper drying and cleaning of maize before storage and control of insects in the store help to control the amount of fungus and toxic degradation in the grain. Discard visibly damaged and discolored grain because they may contain high levels of mycotoxins.

Researchers can measure maize grain quality by a variety of tests, from simple visual observations to more complicated laboratory tests. Manual, mechanical and automated techniques are available for grain quality determination.

Physical measurements. Numerous physical parameters can be determined on maize kernels. Some of the most important characteristics affecting grain quality for various end-uses are kernel size and shape, kernel hardness, and density.

Kernel size and shape. Uniformity of size and shape may be important for industrial processing. Uniformity may also affect the cooking uniformity of maize grain.

Kernel hardness. Kernel hardness reflects the ratio of flinty to floury endosperm, with flinty types having harder kernels. Hardness also indicates the extent of internal cracks and fissures, which can lead to losses during processing and storage. Instrumentation is available for measuring kernel hardness but is used more for research than for commercial purposes.

Kernel density. Kernel density is the weight per unit volume of kernels. Several methods are available for measuring density. These methods are highly correlated with kernel hardness, and require no elaborate equipment. Density is particularly useful in predicting dry milling properties.

True density is measured by displacement of liquid. Ethanol and toluene are often used and converted to water displacement as a standard for specific gravity. True density can also be determined by using air or helium comparison pycnometers.

Factors affecting specific gravity are:

- ratio of flinty to floury endosperm (flint types are more dense);
- relative composition of starch, protein, oil, and water (with specific gravities of 1.5, 1.1, 0.9, and 1.0, respectively);
- moisture content (higher moisture content results in higher density).

Test weight is a measure of bulk density obtained by weighing a specified volume of grain. Test weight reflects both the kernel density and the way the kernels pack. It is useful in determining the size of container needed for a given weight of grain. Kernel shape and density are important determinants. Flat maize kernels have lower test weight than round kernels. Test weight is fairly independent of kernel size. Moisture content affects test weight values.

The flotation test is also used to compare densities of different maize samples. In this method, a specified number of kernels is placed in a solution (for example sodium nitrate) of known specific gravity (for example 1.275). The number of kernels that float is calculated as a percentage of the total. Floury types have a higher percent of floaters than flint types. For maize that has been dried at excessive temperatures, this method is not useful.

Chemical measurements. Chemical measurements determine the composition of maize kernels. Established techniques are available for routine determination of protein, fat, ash, crude fibre, sugars, and starch contents as well as amylose content of starch/flour.

Rheological measurements. Pasting viscosity of starch/ flour is measured with the conventional Brabender viscoamylograph or the Rapid viscoanalyzer. Apparent viscosity is measured using viscometers.

Effects of genotype and environment. Environmental conditions may have some efect on kernel characteristics. For example, warmer growing conditions are associated with an increase in the proportion of flinty endosperm and a decrease in oil content. The composition of starch (amylose : amylopectin ratio) and oil (degree of saturation) may also be affected by temperature. Deficiencies of soil nitrogen reduce the protein content of the grain.

Varieties differ greatly in physical and chemical properties of the grain. Where objectives are clear and rapid screening techniques are available, selection in a breeding program can modify such traits.

Industrial dry milling. In general, maize quality attributes such as high test weight, high percentage of horny endosperm, low broken maize and foreign matter and low breakage susceptibility are desirable for dry milling.

Maize types with a high proportion of horny endosperm are hard. Hardness of maize kernels, an important intrinsic characteristic, affects power requirements for grinding, dust formation, kernel and bulk density and yield of dry milled products, especially grits.

Dry milling requires kernels that are free of detectable mycotoxins. Kernel size and shape are also important.

Too large a proportion of small kernels, such as those from the tip of the ear, are objectionable.

Traditional dry milling. In areas where the whole maize kernel is ground or pounded, producers may prefer floury types for ease of processing and high flour yield.

In other regions, the pericarp is removed before grinding or pounding. In that case, flint types may be preferred because the pericarp can be removed without cracking the kernels, although more energy is required in the process.

Hard kernels may require re-grinding to produce smooth flours. Another factor to consider is storability. Soft kernels are susceptible to insects, ear rots, and possibly aflatoxin.

Industrial wet milling. Quality factors such as low percentages of broken or damaged kernels and foreign matter, and high test weight, are desired for maximum starch and oil yields in the wet milling process. If oil is an important end product, the maize should have a large germ and high oil content. For starch production, a smaller germ that is easily separated from the endosperm is preferred.

Starch, amylose, fat and protein contents as well as water absorptivity of grains are other quality parameters of importance in maize wet milling.

Some special types of maize are used for specific purposes in wet milling. In waxy maize, the starch in the endosperm consists almost entirely of amylopectin (branched chain molecule).

Amylopectin is useful in food and industrial processing. There are also high amylose varieties in which the starch consists of nearly 85 % amylose (unbranched chain molecule).

Amylose also has specific industrial applications. Both mutations are caused by single recessive genes. The relative proportion of amylose and amylopectin affects the cooking properties of the starch.

Traditional wet milling. In traditional wet milling, the yield of starch paste is of primary importance. The desired type has a relatively large endosperm that is easily separated from the pericarp and germ. Very flinty maize is probably not desirable, but for dishes where the maize is steeped for a long period before grinding, harder maize may be acceptable.

Green maize. Although green maize is a major end-use of maize in some areas, relatively little information is available on factors associated with green maize quality. It appears that consumers prefer varieties high in sugar content, with tender kernels and little chaffiness. Large ears may bring a better price than small ears in the market.

Sweet corn. Several mutations are responsible for the sweet flavor characteristic of sweet corn. Most sweet corn varieties are susceptible to diseases and insects that attack maize in tropical climates.

Su locus. A recessive gene *(su)* at this locus interferes with the conversion of sugars to starch. The sugar content of homozygous recessive genotypes *(su su)* is twice that of normal maize at the green stage. The level of water-soluble polysaccharides is 8-10 times greater than in normal maize. Varieties with this mutation remain at peak quality for a relatively short period in the field and after harvest.

Se locus (sugar enhancer). A recessive gene at this locus enhances the effect of the *su* gene. Homozygous recessive *se se su su* genotypes have a higher sugar content than *su su* genotypes and maintain their quality for longer periods.

Sh2 locus (shrunken 2). Homozygous recessive *sh2 sh2* genotypes have a higher sugar content than *su su* types. There is no conversion of sucrose to starch and the levels of water-soluble polysaccharides are low. Shrunken 2 varieties maintain acceptable quality for a longer period during harvest compared to *su su* types and have a watery rather than a creamy texture.

Popcorn. Popcorn varieties have a relatively impervious layer of flinty endosperm surrounding the outside of the kernels which traps gases as the maize is heated. The higher the content of flinty endosperm in the grain, the greater the popping expansion of the kernels.

Animal feed. Farmers prefer yellow maize as animal feed because the pigments in the kernel impart a rich yellow color to egg yolks and broilers. Some of these pigments may have vitamin A activity, but there is not necessarily a close correspondence between the depth of color observed and vitamin A content.

7 Bibliography

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8 Suggestions for trainers

If you use this Research Guide in training ...

Generally:

- Distribute handouts (including this Research Guide) to trainees one or several days before your training activity, or distribute them at the end of your presentation.

- Do not distribute handouts at the beginning of a presentation, otherwise trainees will read instead of listen to you.

- Ask trainees not to take notes, but to pay full attention to the training activity. Assure them that your handouts (or this Research Guide) contain all relevant information.

- Keep your training activities practical. Reduce theory to the minimum that is necessary to follow the practical exercises.

- Use the questionnaire on page 4 (or a selection of questions) for examinations (quizzes, periodical tests, etc.). Allow consultation of handouts and books during examinations.

- Promote interaction of trainees. Allow questions, but do not deviate from the subject.

- Control your time.

Specifically:

- Discuss with trainees their experiences and problems of maize nutrition (10 minutes).

- Present and discuss the content of this Research Guide, considering the study materials listed on page 3 (45 minutes).

  Have samples of different maize dishes available.

  You may photocopy the illustrations of the Research Guide on transparencies for projection with an overhead projector.

- Conduct the practicals suggested on page 3 in groups (3-4 trainees per group; 2 hours). Make sure that each trainee has the opportunity to practice. Have resource persons available for each group and practical.

  Organize your practicals/demonstrations well. Keep trainees busy. Prevent trainees from scattering around the room.

- Visit farms, markets and processing installations to analyze the importance of maize quality.

International Institute of Tropical Agriculture	(IITA)
Institut international d'agriculture tropicale	(IITA)
Instituto Internacional de Agricultura Tropical	(IITA)

The International Institute of Tropical Agriculture (IITA) is an international agricultural research center in the Consultative Group on International Agricultural Research (CGIAR), which is an association of about 50 countries, international and regional organizations, and private foundations. IITA seeks to increase agricultural production in a sustainable way, in order to improve the nutritional status and well-being of people in tropical sub-Saharan Africa. To achieve this goal, IITA conducts research and training, provides information, collects and exchanges germplasm, and encourages transfer of technology, in partnership with African national agricultural research and development programs.

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