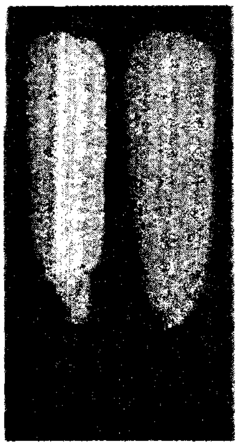
UNIT 12 CHARACTERISTICS AND CHEMISTRY OF COARSE GRAINS

Structure



Maize Cob

Sorghum Plants

Millet Plants

12.0 OBJECTIVES

After reading this unit you would be able :

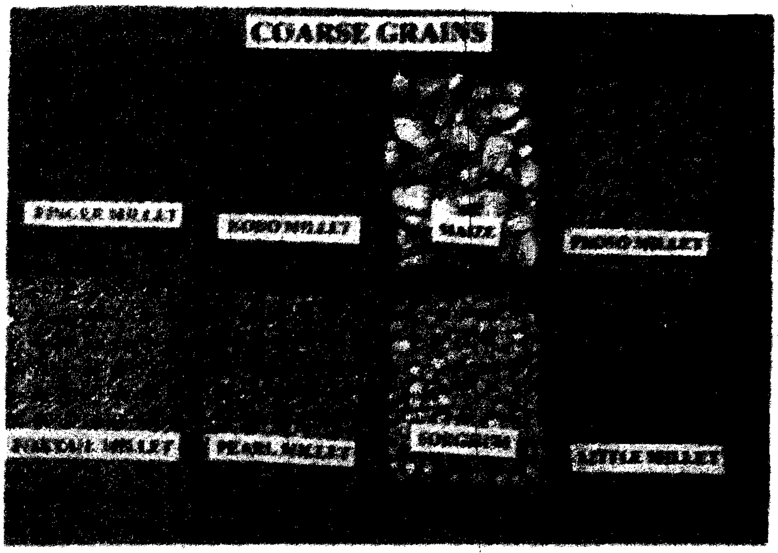
- to describe the pattern of production and utilization of coarse grains;
- to elucidate morphological, structural features *vis a vis* grain constituents viz., carbohydrates, protein, fat and micronutrients and neutraceuticals; and
- to address the challenges of processing technologies in relation to product quality, diversification and nutritional characteristics.

12.1 INTRODUCTION

Coarse grains are cereals that belong to grass family (*Poaceae*). They are also called **MILLETS** since their plants bear a large number of grains on their cob or panicles. The coarse grain crops are hardy in nature, that grow under adverse agro climatic conditions and can be grown in regions with comparatively lower rainfall. Foods based on these grains possess greater sustainability for persons involved in heavy manual work. These grains have longer shelf stability compared to rice and wheat.

India, Africa and Central America are the major coarse grain producing regions. Following are the coarse grains with their botanical names:

Maize (Corn, *Zea mays*), Sorghum (Jowar, *Sorghum bicolor*), Pearl millet, (Bajra, *Pennisetum glaucum*). Finger millet (Ragi, *Eleusine coracana*), Foxtail millet (Italian millet,*Setaria italica*), Kodo millet (Varagu, *Paspalum scrobiculatum*), Little millet (Samai, *Panicum miliare*) and Barnyard millet (Banti Echinochlova frumantaceae), Proso millet (Common millet or French millet, *Panicum miliacium*). Barley (*Hardium Valgare*) (*Jau, Javegodhi*) is also a an important cereal which is mostly used in malt preparation and alcoholic beverages.



Barnyard millet

Fig. 1: Variety of coarse grains

Maize, Sorghum and Pearl millet are designated as major millets and the other crops are called minor millets or small millets due to their size and little coverage both in area and production. These grains are also staples of the future food security and it is imperative that these crops are to be redefined as "Nutritious Cereals" since they contain considerable quantity of vitamins, minerals, dietary fibre, **phytochemicals or neutraceuticals**.

12.2 PRODUCTION AND THEIR PRESENT UTILIZATION

World production of coarse grains, rice and wheat are presented in Table 1

Table 1: Cereal production in the world and their share
(Year 2003-04)

Crop	Production (million.tonns)	Share %
Maize	644.0	**34.20**
Wheat	560.0	29.70
Rice(milled)	390.0	20.70
Other coarse grains	290.0	**15.40**
Total	**1884.0**	**100.0**

It can be seen from the Table 1 that maize tops the share, followed by wheat and rice. The other coarse grains constitute the remaining crop. As regards Indian scenario, it can be inferred from the Table 2 that the production of coarse grains are fluctuating in the last five years. While rice tops the list followed by wheat and coarse grains. The production of coarse grains was highest in the years 2001-02 and 2003-04, and lowest in the year 2002-03.These can be attributed to the diversion of land for other crops, failure of monsoon and lack of market demands.

Table 2: Cereal Production in India (Year wise)
(Million Tonnes)

Year	Crop		
	Rice	**Wheat**	**Coarse grains**
1999-2000	89.68	76.37	30.34 **(15.45)**
2000-01	84.98	69.68	31.08 **(16.73)**
2001-02	93.34	72.77	33.94 **(16.97)**
2002-03	72.66	65.10	25.29 **(15.51)**
2003-04	87.00	72.06	33.72 **(17.50)**

Figures in the parentheses indicate share (%) Current production pattern of some of the coarse grains in India is presented in Figure 1(a). It can be seen that pearl millet tops the list (11.79 mill tonnes) followed by maize (10.68 MT), where as sorghum production is only 7.33MT. Contribution of small millets is 3.92 MT totaling 33.72 MT.

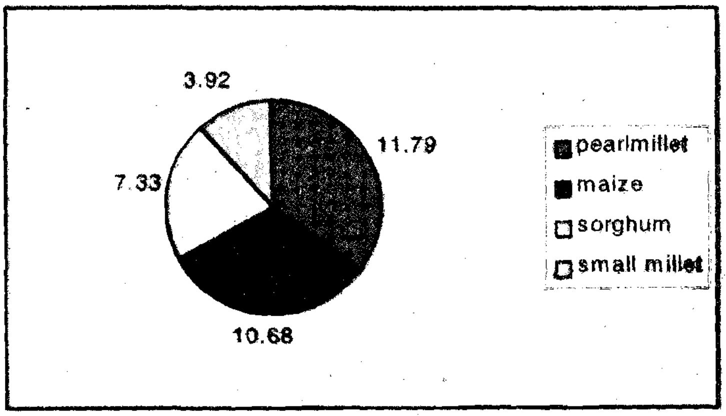


Fig. 1(a): Production of coarse grains in India (year 2003-04)
(Million Tonnes)

It is to be noted that productivity of maize in the U.S.A. is about 8 tonnes /ha where as Indian average yield is less than 2 tonnes/ha. There is a lot of scope to improve the production of coarse grains and consequently there is a strong need to improve their utilization pattern, through appropriate processing, value addition and diversified uses. Price support is another important factor.

Maize is a crop predominant in Karnataka, Bihar, Himachal Pradesh, southern Orissa and parts of Andhra Pradesh and Tamilnadu. Sorghum is a principal staple food of Maharashtra and of considerable importance in Karnataka, Madhya Pradesh, Tamilnadu & Andhra Pradesh.

Pearl millet is popular in Rajasthan, Gujarat & Maharashtra states, small millets are region specific. To improve productivity and nutritional value hybrids and, composites such as Ganga, Vijaya, Deccan,Shakti-1,(Opaque 2,Quality Protein Maize), Shaktiman-1and -2are popular in maize. M-35-1, Maldandi, Mooguthi, Phule Yashoda, CSH 5, in sorghum and Indaf varieties in finger millet are popular.

Efforts of CIMMYT in Mexico, ICRISAT, in India and Purdue University in the U.S.A. and several agriculture universities in, under All India Coordinated crop Improvement Projects of ICAR are responsible for improving the productivity and expansion of these crops. According to experts, the average Yield of coarse grains in India should be improved by 16% by 2010 and by 36% by 2020 to meet the domestic demand.

Utilization of coarse grains

Coarse grains are used for food, feed, and industrial purposes. In India, maize is made into unleavened bread (**roti**), thick porridge (**mudde** or dumpling) thin porridge (gruel), flakes, etc. The cereal forms a base for starch, syrup, glucose and oil production. Maize grits and semolina are used for upma, kesari bhath. The pattern of utilization of maize is presented in Fig.2

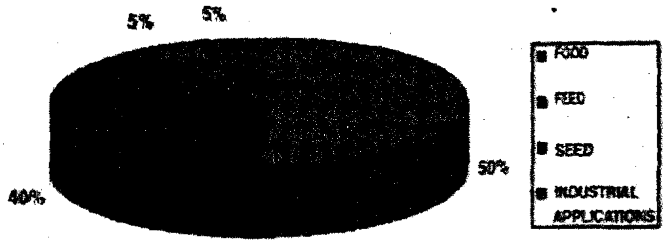


Fig. 2: Pattern of Utilization of Maize in India

There are innumerable uses of maize viz. popcorn, sweet corn, baby corn. Maize is known to be a raw material for 1000 products.

Similarly, sorghum is used in roti, porridge, and dumpling preparations. Out of 7.3 million tons of production annually, 80% is used as food and the rest is utilized for poultry, alcohol, starch and dairy industries as shown in Fig.3. Projected utilization pattern in the year 2010 is also presented.

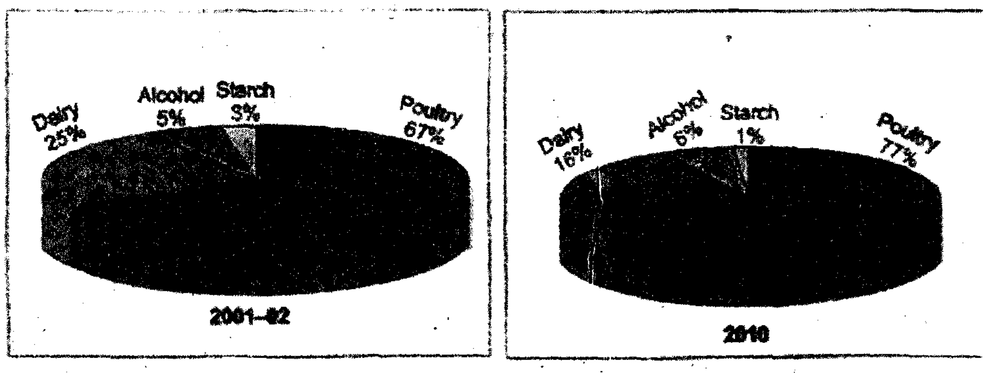


Fig. 3: Relative contribution of alternate uses of sorghum in India

12.3 GRAIN MORPHOLOGY AND STRUCTURE, SPECIAL FEATURES OF THESE GRAINS

All the coarse grains and rice, wheat have similar gross structure. The outer fibrous bran layers made of pericarp, seed coat (tegmen, testa), nucleus covered with a waxy cutin material. Below this layer lies aleurone layers, and the predominant endosperm. Germ, the reproductive part is located in the periphery. Rice (paddy), barley and oat have a set of husks or hulls called lemma and palea. Gross structure of maize (corn) and sorghum is presented in

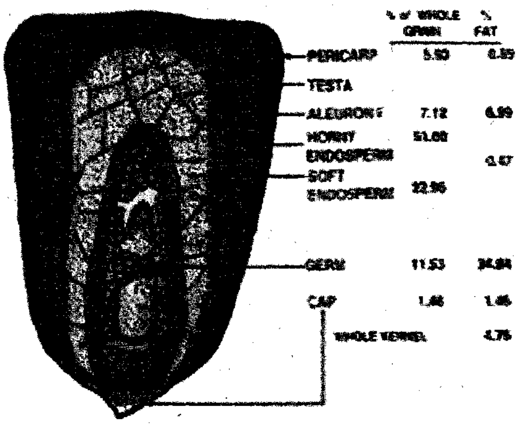


Fig. 4: Longitudinal Section of the Corn Kernel Morphology and Composition

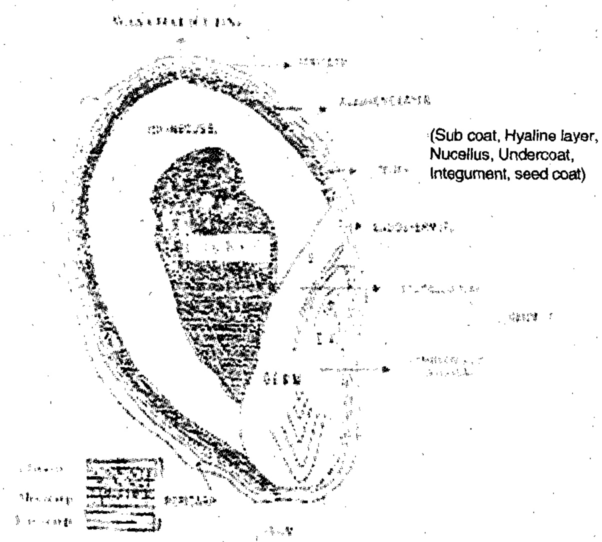


Fig. 5: Anatomical parts in a longisection of a sorghum kernel

The distribution pattern of these anatomical parts in some of the grains is presented in the Table 3 below:-

Table 3: Anatomical parts in grains (%)

Part	Paddy	Wheat	Maize	Sorghum
Husk	20.0	—	—	—
Bran	6.0	17.0	15.0	7.9
Germ	2.0	3.0	11.5	9.8
Endosperm	72.0	80.0	73.5	82.3

While wheat and maize have large bran layers, maize and sorghum have big germ. Some of the cereals have an outer thin waxy coating viz cutin to protect from moisture. Wheat, sorghum and maize have thick bran layers since they have loose husk. Cereals like rice wheat, maize & millet are classified as caryopsis in which pericarp and seed coat are fused. In finger millet these parts are not fused and hence it is called an utricle.

Wide variation in both size and shape vary in all the grains can be seen in Table 4:

Table 4: Dimensions and weight per 1000 of grains

Cereal	Length (mm)	Width (mm)	Weight (g)	Range (g)
Maize	8-17	5-15	324	150-600
Sorghum	3-5	2-5	28	8-50
Wheat	5-8	2.5-4.5	37	27-48
Rice(milled)	5-10	1.5-2.85	20	10-25

Variation in grain size is very wide in Maize as can be seen in Fig 6

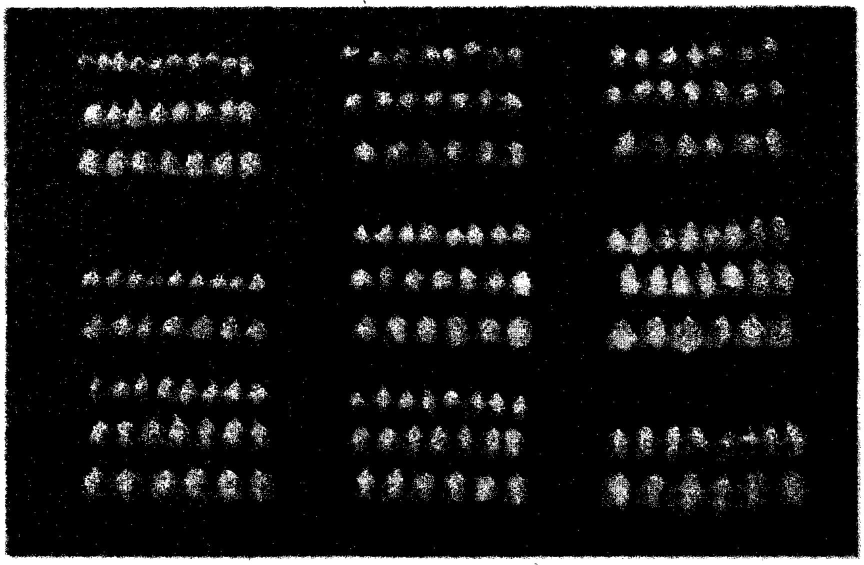


Fig. 6: Variation in Size and Shape in Maize

Shape and size of the grains are to be taken in to consideration for designing storage structures and processing equipment. Both in Maize and Sorghum there are two types of endosperms Viz.soft, floury and hard, horny (corneous) types.

Large sized grains generally have bigger floury areas which deleteriously affect milling quality .For clean removal of bran and germ, large flat grains are desirable in maize (Fig. 7).

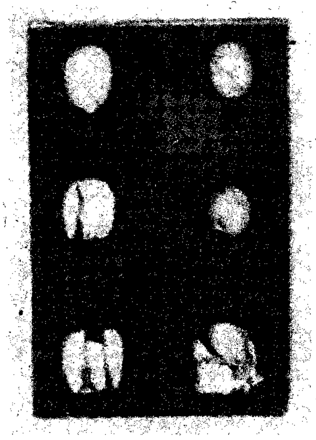


Fig. 7: Mechanism of degerming in flat and round grains

To obtain large number of flat grains in maize, cobs should be large, cylindrical in shape with minimum number of rows (see Fig 8 and Fig 9). In sorghum, small round grains can be pearled successfully. Production of grits, whole grains, semolina and flour with low fat and low fibre can be achieved by suitable selection of varieties, size grading, pretreatment, and equipment. Thus, large sized germ in maize, when wet milled, yields edible oil.

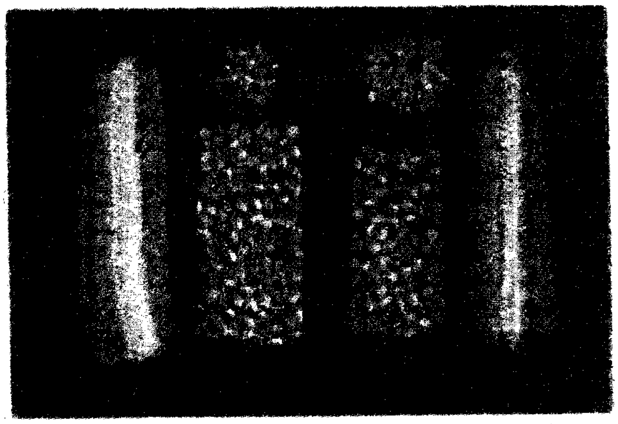


Fig. 8: Influence of Cob on Size and Shape of Grains

Maize breeders are working towards development of such process - friendly varieties. Prior to milling, appropriate size grading or sifting the maize and sorghum bulk will also help in separation of small/ large flat grains so that low fat , low fiber grits and flour are produced. Grain separated by such means can be processed in a mini grain mill or in a modified huller or high capacity pilot mill.

Production of low fat, low fibre grits or flour are good raw materials for value Addition as well as diversified uses of coarse grains.

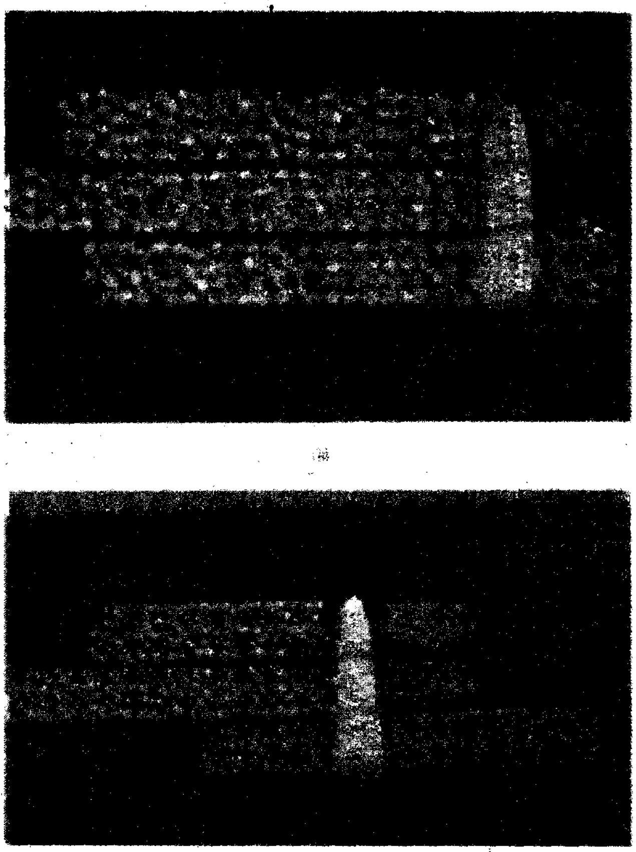


Fig. 9: Influence of Cob Type on Size and Shape of Grains

12.4 PROXIMATE COMPOSITION AND NATURE OF MAJOR CONSTITUENTS

Since coarse grains form staples for many populations, it is pertinent to know their chemical constituents. It can be seen from Table 5 that the major constituent of all cereals is starch (carbohydrates) which provides energy and has many functional properties.

Table 5: Proximate Composition of cereals (%) at 12% moisture

Constituent	Maize	Sorghum	Rice (milled)	Wheat	Pearl millet	Barley
Protein	9.2	10.4	6.8	11.8	11.6	11.5
Fat	5.7	3.2	0.5	2.2	5.1	1.3
Crude fibre	2.3	4.8	0.3	1.2	2.0	3.9
Ash	1.6	3.0	0.6	1.6	2.0	1.2
Carbohydrate	69.2	66.6	79.8	71.2	67.3	73.1

Maize, sorghum, pearl millet and wheat and small millets have higher proportion of protein, fat, fibre and ash (minerals) compared to rice due to their genetical properties and thicker bran. The nutrional quality of these grains will be discussed later. The endosperm of yellow maize has considerable amounts of carotenoids (which are precursors of Vitamin A). Incidentally you may know that yellow colour to egg yoke is due to the carotenoids. S maize can be considered as a good source of Vitamin A.

12.4.1 Starch content- Amylose and Amylopectin

Amyolose (glucose molecules with straight chain) and amylopectin (glucose with branched chain) are constituents of starch which have considerable role in functional properties. Besides providing energy and their application in several industries viz. brewery, glucose/Fructose syrup, textiles are noteworthy. Normally, amylose content in maize is about 25-30% and in sorghum the values are 20-30%. High amylo maize having more than 50% amylose and waxy types (amylose 0%) are produced for special purposes, Wet milling, viscosity of slurries, thickeners and other industrial applications are decided by ratio of amylose and amylopectin.

12.4.2 Protein content and amino acid composition

Protein is required for growth and replacing body proteins lost due to wear and tear. Protein serves as enzymes also for carrying various metabolic activities. Although maize and sorghum contain higher proportion of protein compared to rice, their biological value is lower due to deficiency in lysine an essential amino acid. In addition, the ratio of leucine and isoleucine is also higher in these grains. This anomaly disturbs tryptophan availability (another essential amino acid) resulting in a disease called pellagra a situation of diarrhea, dermatitis, and dementia and in acute condition even leads to delirium. However, breeding of improved varieties of maize has obviated this problem. It can be observed in the Table 6 that use of **Opaque-2 (Quality protein maize QPM)** which has higher proportion of lysine compared to normal maize resulting in better Biological value (BV) and Net protein utilization (NPU). Further, as indicated earlier, sorghum and wheat have lower BV and NPU compared to rice due to lower lysine content.

Table 6: Nutritive values of cereals

Crop	Protein (%)	Lysine*	Leucine*	Isoleucine*	Tryptophan*	BV (%)	NPU (%)
Maize	9.2	2.6	12.5	3.7	0.5	61.0	58.0
Opaque-2	10.69	4.82	-	-	1.1	75.8	63.3
Sorghum	10.4	2.0	13.6	3.8	1.0	59.2	50.0
Rice	6.8	3.8	8.2	3.8	1.4	74.0	73.8
Wheat	11.8	2.9	6.7	3.7	1.1	55.0	53.0

(*) g per 16 gram nitrogen

12.4.3 Oil content, lipase role in keeping quality

It is generally believed that cereals are rich in only carbohydrates. But the fact is they also contain considerable amount of oil or invisible fat which have profound economic and nutritional implications. The oil is concentrated either in germ and / or aleurone layers. In maize and sorghum, oil is concentrated in germ fraction to the extent of 33.2 and 28.1% respectively. But bran of maize has low oil content (1%) and that of sorghum is 4.9%. However during normal milling in mechanical equipment clean separation of different anatomical parts are not achieved. Theoretically endosperm forms 70 to 80 % of the total kernel, but in practice, yield will be around 60 to 70% only or even less.

In both maize and sorghum, oil degrading enzymes (lipase and lipoxygenases) are located in germ and hydrolyse the oil into free fatty acids leading rancidity. Hence any contamination of endosperm with bran and germ leads to deterioration. Hence milling with appropriate technology can result in low fat and low fibre grits. It is also possible to stabilize the grain to inactivate lipolytic enzymes to improve storability of all the milling fractions. By proper milling either by wet or dry process one can separate the germ especially in maize and extract good quality edible oil. In many maize growing countries, maize oil is techno economically produced and consumed. Maize oil is nutritionally superior. In the Table 7 fatty acid profile of maize oil is presented. The oil is rich in essential fatty acid: linoleic acid (60.1%). The oil rich in phospholipids and tocopherols which helps in reducing cholesterol and good choice for heart patients. In addition, it has high smoke point and suitable for frying foods. Efforts are to be made to extract oil from sorghum also.

Table 7: Fatty acids in Sorghum & Maize oils

Fatty acid	R Chain Length No. of double bonds	Percent of total fatty acids	
		Sorghum	Maize
Palmitic	C 16.0	12.9	11.1
Palmitoleic	C 16.1	0.9	0.1
Stearic	C 18.0	3.2	1.8
Oleic	C 18.1	37.7	25.3
Linoleic	C 18.2	38.4	60.1
Linolenic	C 18.3	2.9	1.1
Arachidic	C 20.0	—	0.2
Essential fatty acids	—	**41.3**	**61.2**

12.4.4 Constituents from bran fraction

As already indicated on page-6, all cereals have bran (outer cover) a germ (reproductive part) and predominant endosperm. During milling / refining/ decortication, depending on the efficiency of the milling system, variety, 8 to 30% of bran combined with germ and occasionally endosperm are collected. During milling considerable quantity of ash, fibre & oil are removed from kernel as shown in Table 7A

Table 7A: Effect of milling / pearling on chemical constituents in millets (%)

Grain	Processing	Protein	Oil	Ash	Crude fibre
Maize	Whole grain	11.2	4.8	1.7	1.9
	Refined grits	10.5	0.9	0.7	1.0
Sorghum	Whole grain	12.0	2.6	2.0	3.1
	Pearled	11.5	1.9	1.4	1.7
Pearl millet	Whole grain	10.6	5.8	1.8	1.2
	Refined flour	6.3	3.0	0.8	0.2

From the above table, it can be seen that there is a significant loss of protein in the case of pearl millet and not so much loss in the case of maize and sorghum. As far as other constituents like oil and crude fibre, there is a significant loss in all these constituents during pearling of all the three grains.

The commercial bran where germ is not separated in clean form, contains protein rich in lysine, oil, fibre, ash (minerals), starch, vitamins, pigments, fibre and polyphenols (tannins). **Presence of tannin in some millets imparts resistance to pests, birds, diseases and premature sprouting.** Major constituents in cereal brans are presented in Table 8.

Table 8: Average composition of bran/germ of different grains

Crop	Protein (%)	Oil (%)	Ash (%)	Crude fibre (%)
Wheat	11.0	3.6	5.1	9-13.0
Rice	14.4	21.1	8.9	10.0
Maize meal	10.1	5.7	1.2	1.4
Germ meal	14.6	14.0	4.0	4.6
Sorghum bran	8.9	5.5	2.4	8.6
Sorghum germ	15.1	20.0	8.2	2.6
Millet*	18.9	16.4	5.1	3.9

* Semi-wet milling

It can be inferred from the above Table that the cereal brans are rich in all the nutrients. The concentration of these nutrients in germ and bran layers (i.e. non uniform distribution of nutrients) is a technological challenge.

i. Antioxidants

The bran layers are rich in tocopherols (vitamin E), vitamin A (in yellow maize), Presence of so called antinutrients viz polyphenols are to be considered afresh.

Scientific researches carried out in late 1970s have shown that fibres and polyphenols (tannins) have hypoglycaemic, anticholesteric, anticarcinogenic, slimming properties in humans. The polyphenols also serve as antioxidants.

The antioxidants are compounds that get oxidized themselves thus depriving free oxygen for enzymes in the animal cells. In this way they protect the cells from oxidation. Just as oxygen can cause metals to rust, oxygen can also oxidize living cells and result in irreparable damage. The antioxidants have properties of repairing DNA, protein, lipids etc, which in return avoid diabetes, cataract, atherosclerosis, neuro degenerative diseases like Parkinson, Alzheimeirs. Sorghum and millets are rich in these antioxidants in bran layers. Finger millet has also very high proportion of calcium (344mg, %) and useful polyphenols that prevent incidence / cure gastric disease caused by bacterium *Helicobacter pylori*. Some pigments present in pearl millet that are undesirable can be eliminated by treating with organic acids and tamarind extract.

ii. Dietary Fibre

These biochemical compounds are found in cereal brans which have protective action against **obesity**, reduce fecal bile acid concentration, colon carcinogenic substances. They also retard tumour formation, improve intestinal microflora (which produce short chain fatty acids in proximal colon) and provide important energy for the mucosa. They have major role in **obviating constipation.**

Hence cereal brans can be used as food adjuncts in bakeries. Some of the neutrceuticals viz, fibers or polyphenols can be extracted and supplemented in our diets for health benefits. Similarly protein, oil, vitamins and minerals can also be extracted. Extraction of phytin (anti caries agent), oryzanol (anti oxidant from rice bran) are being industrially done and marketed.

12.5 LET US SUM UP

The foregoing lesson explains in detail the production pattern of coarse grains (**nutritious cereals**). These grains forming about 17% of the total cereal production is worth more than Rs.16,000 crores.

The structural features of the cob in maize and **anatomical peculiarities** of each grain type are highlighted in relation to technological, nutritional and product quality. Chemical profiles of the coarse grains which have considerable influence on nutritional value is emphasized.

The starch and its composition, the drawbacks in protein quality especially the **limiting amino acid lysine, imbalance in isoleucine and leucine that cause pellagra disease** in maize and sorghum eaters are described. The importance of germ in maize as a source of edible oil containing good fatty acids is to be noted. The need for stabilizing lipases which degrade oil is very important for techno - economic benefits. If all the maize produced in the country is well processed, **more than 40 thousand tons of high quality maize oil can be obtained.**

The most neglected bran and germ of some of the grains have to be processed for industrial exploitation through **blending of refined bran** with wheat or rice products or extraction of **neutraceuticals: dietaryfibre**, vitamins, **polyphenols** These technological innovations can change poor image of coarse grains. While wheat is the king, rice queen of cereals, coarse grains will truly be princes. It is envisaged that appropriate understanding of the structural features of theses grains and suitable pretreatment and processing followed by **value addition and diversification**, will definitely lead to improvement of health of consumers and benefit farmers with better returns and overall improvement of grain industries. Efforts are on to utilize under-utilized wheat and rice mills for processing coarse grains for better techno economic scenario.

Check Your Progress

Note: a) Use the space given below for your answers.
b) Check your answers with those given at the end of the unit.

1. What are coarse grains and give their regional distribution?

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2. Describe pattern of production and utilization of coarse grain s in the country.

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3. Give morphological and inner details of coarse grains and bring out salient differences among them.

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4. Explain the role of size and shape and endosperm structure on processing qualities of maize.

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5. Bring out salient differences in nutrional properties of coarse grains and their implication on health.

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6. What steps are to be taken to make coarse grains and anatomical parts shelf stable.

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7. What are merits and demerits of cereal brans and how we can use them techno economically.

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12.6 KEY WORDS

Maize, Sorghum (Jowar), Pearl, millet (Bajra), Finger millet	:	Then grains are produced all over the world and classified as coarse grains and belong to the grass family (Poaceae).
Production	:	India, Africa and central America are the major coarse grain producing countries in the world.
Structure	:	Most coarse grains similar gross structure. The other fibrous bran layers made of pericarp, seed coat and nucleus covered with a waxy cutin material. Below this layer lies ateurone layers and the predominant endosperm.
Chemical Constituents	:	Most coarse grains contain starch (Amyloze and Amylo pectin) Protein, oil and crude fibre.
Antioxidants	:	Antioxidants are compounds that get oxidized themselves thus depriving free oxygen for enzymes in the cells. In this way they protect the cells form oxidation.

12.7 ANSWERS TO CHECK YOUR PROGRESS EXERCISE

1. Coarse grains are cereals (food grains) which can grow in adverse agroclimatic conditions having rough outer covering. Foods based on these grains possess greater sustainability or people involved in heavy manual work. These grains have longer self life and not susceptible to storage insects. These grains are distributed mainly in India, Africa and Central America.
2. Annual production of coarse grains in the last 4-5 years varied from 35.29 to 33.94 million Tonnes in the country. The form 15.40 to 17.50 % of the total production of cereals including wheat and rice. Utilization of maize is mainly for feed (50%) food (40%) purposes. Remaining 5% each to seed and industrial uses. Eighty of % Sorghum is used as food and remaining for polultry, alcohol, starch and dairy industries. Other coarse grains are mainly used for food purposes.
3. Although these grain size and shape vary among different coarse grain, all have outer pericarp, seed coat, aleurone layer, germ and endosperm. In some of these grains, the pericarp and seed coat are fused and thus they are called caryopsis. In finger millet and proso millet pericarp is loosely attached to seed coat and separates out during threshing. Hence they are called utricles. Maize has largest germ among all the coarse grains.
4. Role of size and shape of the cob in maize greatly influences the shape and

size of the grain also. For eg. cobs with large cylindrical shape having minimum number of rows produce large number of process friendly flat grains i.e., large flat grains can easily be processed to produce low fat, low fibre grits i.e., clean separation of bran and germ are achieved. Similarly, tiny grains in sorghum and pearl millet are to be sieved out prior to milling to achieve good pearling.

5. Most of the coarse grains have higher protein content compared to rice, but due to their lower proportion of lysine (an essential amino acid) and imbalance in the leucine and iso-leucine ratio, they have lower nutritional value. Certain colour sorghum varieties have higher proportion of tannin in bran layers. Judicious pearling of these grains can greatly improve functional and nutritional properties. The characteristic starch properties of some these grains impart greater sustainability and satitty compared to rice and wheat. Some of the phytochemicals present in coarse grains can be extracted and added to the flours of rice and wheat to enhance their nutritional value.

6. Flours from coarse grains do not have good shelf life due to the presence of fat splitting enzymes like lipases. Hence they are to be hydrothermally treated, optimally pearled and processed and mixed with suitable additives to impart better shelf stability and functional properties.

7. Although cereal grains are rich in oil, protein, vitamins, minerals, antioxidents and dietary fibres they have certain antinutrients and poor shelf life. However they are rich in dietary fibre. After suitable processing, they can be used for supplementing the dietary level of products obtained using the refined flours from wheat and other grains. Many phytochemicals like polyphenols and tannins could be extracted and used for pharmaceutical purposes.

12.8 SOME USEFUL REFERENCES

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