Literature Review

2. LITERATURE REVIEW

2.1. Water and industry

Water is one of the most important inputs for economic development. The water demand has multiplied as a result of population growth, agricultural expansion, as well as industrial development and a rise in the standard of living (Winpenny *et al.*, 2010) [15] .

Industry relies on water for all levels of production. It is used as raw material, solvent, coolant, transport agent, and energy source. (Emest and Ronald, 2006; UN, 2003) [16, 17]. Also in Egypt, 99% of the industrial water are freshwater and from River Nile. The distribution of water consumption between the various sectors in Egypt was represented in Table 1, by Gad and Ramadan (2009) [18].

The analysis of the industrial water needs depends on the industrial units and production sizes. The water consumption rates for the industrial unit in Egypt are presented in Table 2, by Abou Rayan and Djebedjian (2000) [19].

Industrial wastewater may be defined as wastewater generated by industrial or commercial facilities. Its quality and quantity may depend on factors such as operating conditions, process raw materials, types of water-using processes and product characteristics (UNESCO, 2006) [6].

Due to increasing water scarcity and costs, manufacturing industries around the world are moving towards the recycling of their process wastewater. (Agana, 2013)[20]. Alexandria is considered as the second industrial city in Egypt where 40% of the whole Egyptian industries are concentrated, especially chemicals, food, spinning and weaving as well as oil industries and fertilizers. The pressing problem is that these industries discharge there wastewater to lake Maryut and the Mediterranean Sea, or to the general sewage system (Meybeck *et al*., 1989) [21].

Table (1): Distribution of water used by sectors in Egypt

Sector	Consumption BCM/annum	Percent
Agriculture	50.8	81.1
Industry	8.8	14.1
Electricity	2.0	3.2
Navigation & winter closure	1.0	1.6
Total	62.6	100

BCM: Billion cubic meters
Source: Gad and Ramadan (2009)[18]

Table (2): Water consumption rates for industries in Egypt

Industry Type	Consumption (MCM/Year)
Pulp and paper	8.00
Textile	1.70
Drink and beverage	2.00
Food	5.25
Mining	6.00
Steel	304.00
Chemical	31.00
Petroleum	4.60
Non-metallic industries	0.14
Steam electric power station	235.70

MCM: Million cubic meters
Source: Abou Rayan and Djebedjian (2000) [(19)]

In developing as well as underdeveloped countries, industrial effluents are released directly or indirectly into the natural water resources, mostly without proper treatment, thus posing a serious threat to the environment (Madhukar and Srikantaswamy, 2013) [(22)].

These impacts can be reduced or avoided by the treatment of this industrial wastewater. Treatment systems differ according to waste type discharge destination and potential reuse, such uses can be quite different as stated in UNEP (1993) [(23)]:

1- Landscape Irrigation: Reclaimed water can be distribution for irrigation of parks, golf courses, football fields, highway medians, and even residential lawns.
2- Industrial uses: industrial facilities and power plants can use reclaimed water for cooling equipment, parts washing and various other manufacturing processes.
3- Construction uses: Reclaimed water can be used for washing aggregate and making concrete.
4- Miscellaneous: Water can be used as a water supply for commercial laundries, for vehicle washing, and flush sanitary sewers as stated at New Jersey division of water quality Technical Manual (Anonymous, 2005)[(24)].

2.2. Food industry

Food processing comprises the methods and techniques used to transform raw ingredients into food; or to transform food into other forms for consumption by humans or animals (Kaushik *et al*., 2009) [(25)]. In principle, the water used in the food industry may be used as process and cooling water or boiler feed water (EC, 2006). [(26)]

The international food industry grew by 1.6% annually over the period 1980-2006 (Winger and Wall, 2006; Selim, 2009) [(27, 28)]. The majority of food processing facilities are characterized by very high water consumption and high organic strength wastewater generation. The sector consumes 46% of raw water and generates 50% of wastewater. The wastewater is often characterized by a high Biological Oxygen Demand (BOD) and a suspended solid (SS) with a high tendency to putrefy is not properly treated (Mori, 2003; Okazaki, 2006; Corcoran *et al.*, 2010) [7, 29-30].

The European Directive 2008/98/EC definition defines waste as: any substance or object which the holder discards or intends or is required to discard (European Parliament, 2008)[31].

However, waste prevention does not only include the reduction of absolute waste amounts but also avoidance of hazards and risks because safety is also of major concern. Considering the waste management options, at the top of the hierarchy stands waste minimization that includes (Riemer and Kristoffersen, 1999) [32]:

- Waste prevention i.e. reduction of waste by application of more efficient production technologies;
- Internal recycling of production waste;
- Source-oriented improvement of waste quality, e.g. substitution of hazardous substances;
- Re-use of products or parts of products, for the same or other purpose.

2.2.1. Characteristics of food industry wastewater

Wastewater can mean different things to different people with a large number of definitions in use (Vigneswaran and Sundaravadivel, 2004; Raschid-Sally and Jayakody, 2008) [33, 34].

Janesiripanich (1995) [35] identified several common sources of wastes generated in food industries as follows:-

- Process water
- Rinsing or washing water
- Transporting water
- Floor and machinery cleaning water or liquid
- Product drainage
- Overflow from tanks or reactors
- Unusable portions of the product
- Spoilt raw materials and rejects

Wastewater recovery and reuse in industry require all the basic steps of quality management. It should involve a comprehensive in-plant survey of processes with wastewater generation, identification of recoverable materials and treatment requirements for such reuse. It should equally undertake evaluation of wastewater quality remaining after segregation of the recovered portion, with specific emphasis on technological implications of appropriate treatment and compliance with effluent limitations (Orhon *et al.*, 2001). [36]

The starch processing industry consumes a lot of water, resulting in a huge amount of industrial wastewater. Unfortunately, this wastewater is mainly discharged into sewerage networks without any treatment, which causes serious environmental pollution problems. The chemical oxygen demand (COD) levels of starch wastewater range from 10 to 30 g/l., and it undoubtedly imposes heavy loads on the environment, causing high expenses in terms of sewer disposal. Fortunately, starch wastewater is rich with biodegradable organic matter and its temperature is relatively high (35 to 40 °C). Moreover, starch wastewater contains a high percentage of carbohydrates, cellulose, protein, and nutrients, representing an important energy-rich source that can potentially be converted to a wide variety of useful products (Jin *et al.*, 2002) [37]

2.3. Motivational factors for recycling/reuse wastewater

Major among the motivational factors for wastewater recycle/reuse are:

- Opportunities to augment limited primary water sources;
- Prevention of excessive diversion of water from alternative uses, including the natural environment;
- Possibilities to manage in-situ water sources;
- Minimization of infrastructure costs, including total treatment and discharge costs;
- Reduction and elimination of discharges of wastewater (treated or untreated) into receiving environment;
- Scope to overcome political, community and institutional constraints.

Reuse of wastewater can be a supplementary source to existing water sources, especially in arid/semi-arid climatic regions. Most large-scale reuse schemes are in Israel, South Africa, and arid areas of USA, where alternative sources of water are limited. Even in regions where rainfall is adequate, because of its spatial and temporal variability, water shortages are created. For example, Florida, USA is not a dry area, has limited options for water storage, and suffers from water shortages during dry spells. For this reason wastewater reuse schemes form an important supplement to the water resource of this region (Vigneswaran and Sundaravadivel, 2004)[33].

Potential reuse of wastewater depends on the hydraulic and biochemical characteristics of wastewater, which determine the methods and degree of treatment required. While agricultural irrigation reuses, in general, require lower quality levels of treatment, domestic reuse options (direct or indirect potable and non-potable) reuses need the highest treatment level. Level of treatment for other reuse options lie between these two extremes (Vigneswaran and Sundaravadivel, 2004) [33].

2.4. Rice starch manufacture

Rice starch is manufactured around the world, but its tonnage is low because of its price. Rice starch contains tiny granules (<5 μm) with a narrow size distribution. In addition, rice starch causes minimal allergic reactions and it's reported as unique, with bland taste, creamy, spreadable, and smooth in texture. These characteristics include hypoallergenicity, digestibility, consumer acceptance, bland flavor, small granules, white color, and increased freeze– thaw stability of pastes, greater acid resistance, and a wide range of amylose: amylopectin ratios. These unique properties have increased rice starch demand in the food and pharmaceutical industries. High purity rice starch with low surface protein-lipid contamination is desired to minimize rancidity during storage and for use as a starting material for chemical modification, fermentation, and industrial applications Rice starch isolation is different from other starches because of its unique protein composition. The isolation process consists mainly of the separation of starch from protein, fiber, and lipid (Mitchell, 2009; Lawal *et al.*, 2011) (38,39)

2.5. Starch and its sources

Starch is found in plant leaves, stems, roots, bulbs, nuts, stalks, crop seeds, and staple crops such as rice, corn, wheat, cassava, and potato. It has found wide use in the food, textiles, cosmetics, plastics, adhesives, paper, and pharmaceutical industries. In the food industry, starch has a wide range of applications ranging from being a thickener, gelling agent, to being a stabilizer for making snacks, meat products, fruit juices (Manek *et al.*, 2005). [40]

Chemically, starches are polysaccharides, composed of a number of monosaccharides or sugar (glucose) molecules linked together with α-D-(1-4) and/or α-D-(1-6) linkages. The starch consists of 2 main structural components, the amylose, as shown in Figure 1, which is essentially a linear polymer in which glucose residues are α -D-(1-4) linked typically constituting 15% to 20% of starch, and amylopectin, as shown in Figure 2, which is a larger branched molecule with α-D-(1-4) and α-D-(1-6) linkages and is a major component of starch (Shen *et al*., 2009; Debnath *et al*., 2013)[41, 42].

Amylose is linear or slightly branched, has a degree of polymerization up to 6000, and has a molecular mass of 105 to 106 g/mol. The chains can easily form single or double helices. Amylopectin on the other hand has a molecular mass of 107 to 109 g/mol. It is highly branched and has an average degree of polymerization of 2 million, making it one of the largest molecules in nature. Chain lengths of 20 to 25 glucose units between branch points are typical. About 70% of the mass of starch granule is regarded as amorphous and about 30% as crystalline. The amorphous regions contain the main amount of amylose but also a considerable part of the amylopectin. The crystalline region consists primarily of the amylopectin (Sajilata, *et al.*, 2006) [43]

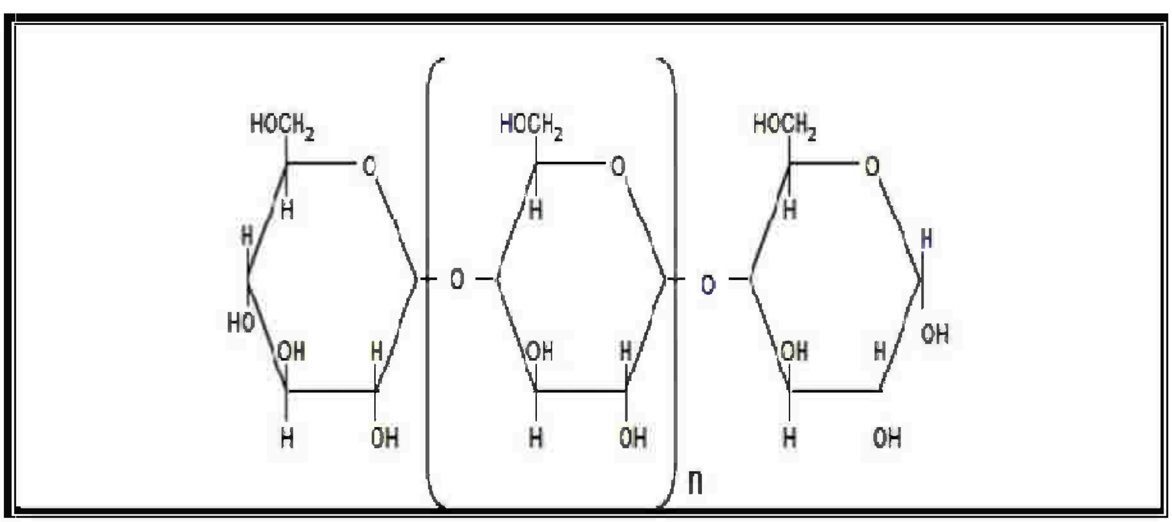

Figure 1: Section of the amylose molecule showing the repeating an hydro glucose unit (Shen *et al*., 2009)[41]

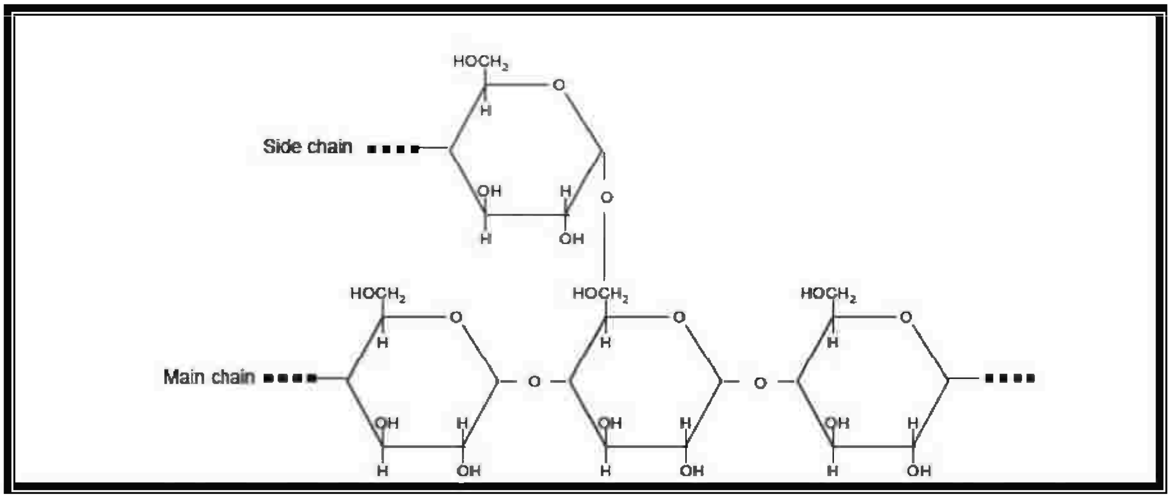

Figure 2: Section of the amylopectin molecule showing the α-1, 4 and α-1,6 chain linkages in starch (Shen *et al.*, 2009)[41]

Additionally to amylose and amylopectin, starch also consists of a small amount of other compounds such as lipids, proteins and phosphates. Figure 3 shows the structure of starch from atomic to granular level. These starches are polar molecules and have different ends. Starch from different sources may vary with regard to several characteristics. These include the shape and size of starch granules, and the composition of starch granules (relative concentrations of amylose and amylopectin, phosphorus, lipid and protein content). Therefore, starch can have different industrial uses depending on the agricultural raw material from which it was extracted (Tolvanen, 2013). [44]

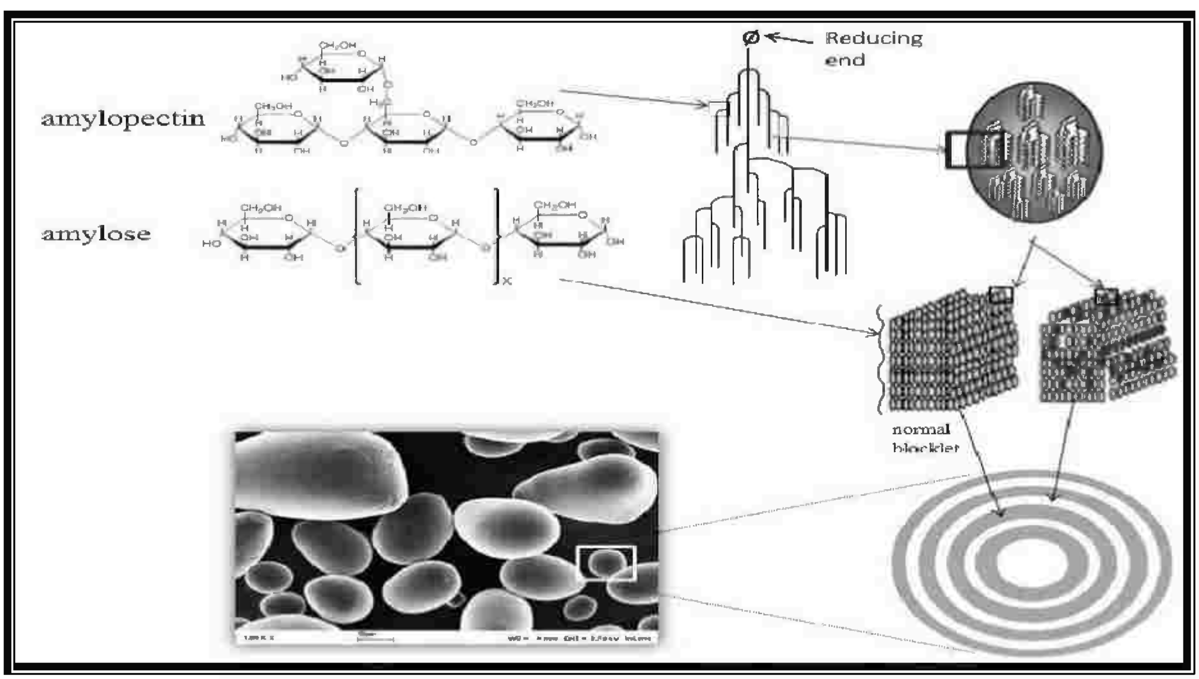

Figure 3: Structure of starch from atomic to granular level starting from amylose and amylopectin to complete granules (Tolvanen, 2013) [44]

2.5.1. Classification of starch and starch derivatives

The starch molecule can be extracted and sold as such (native starch), but it can also undergo several processing operations in order to improve its proprieties and enlarge the range of its uses. Three main groups of starch products can be distinguished (Figure 4):

- ***Native starch*** is the starch chain extracted from raw material, in its original form. It can either be dried (powder) or not (liquid starch).
- ***Modified starches*** are starches modified by a chemical, physical or enzymatic process. They include:

1. Substituted starches: esters and ethers of starch, or cross-linked starches that is more or less resistant to gelatinization.
2. Starch degradation or conversion made through oxidation, acid hydrolysis, dextrinisation or enzyme conversion etc. Starch degradation or conversion reduces starch viscosity and allows the use of starch with higher solids content. It increases water solubility, controls gel strength and can alter starch stability.
3. Physical modification: for instance, pregelatinisation of starch.

- ***Hydrolyzed starches*** (Sweeteners): the starch chain can be broken into smaller glucose chains via hydrolysis.

From 2001 to 2008, as shown in Figure 5, the production volume of all types of starch products witnessed a strong growth, the growth rate increasing with the enlargement of the range of starch products: 14% growth for native starches, 24% for modified starches and 24% for hydrolysed starches (Fuglie *et al.*, 2006; Duval *et al.*, 2010). [45, 46]

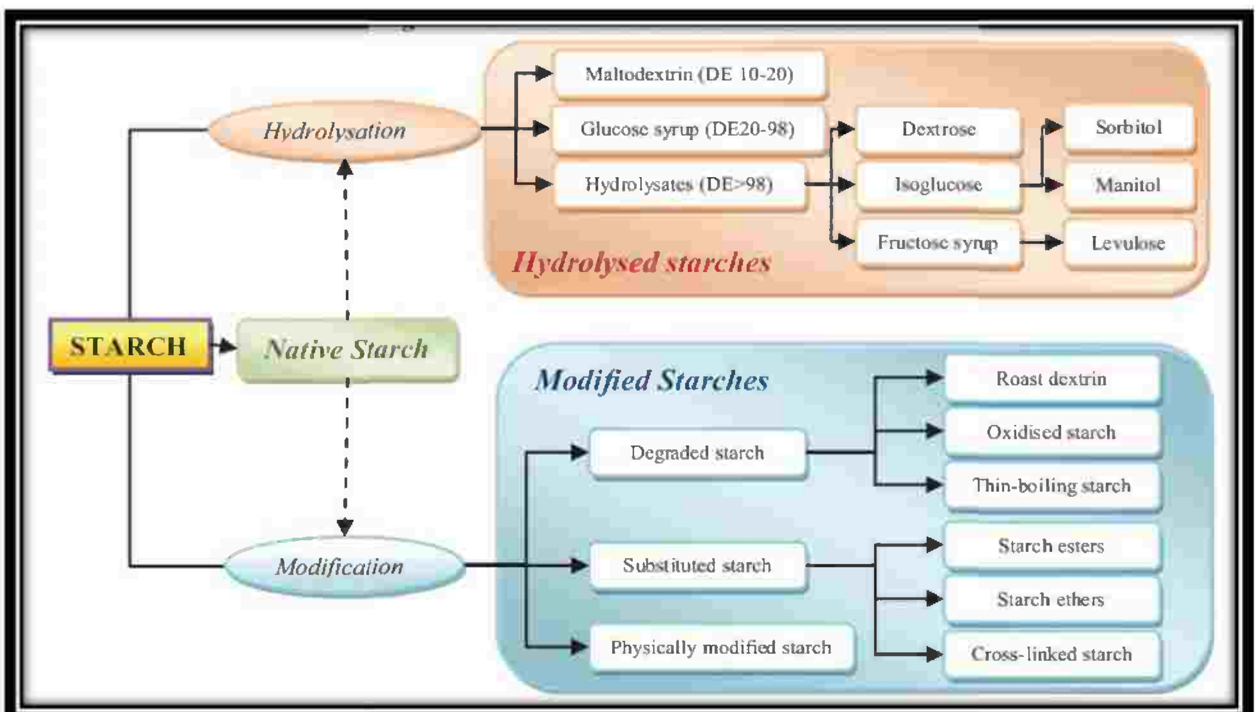

Figure 4: Classification of starch and starch derivatives (Agrosynergie, 2010) [47]

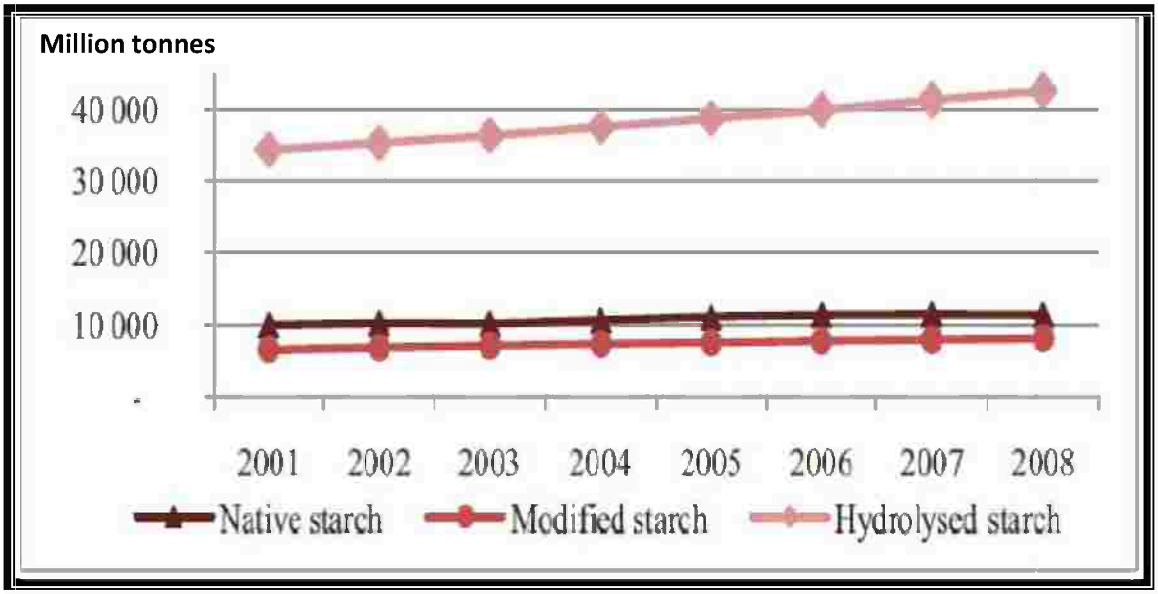

Figure 5: Development of world output of all types of starch products, from 2001 to 2008 (Agrosynergie, 2010) [47]

2.6. Raw materials in rice starch industry

Raw materials used to produce starch vary from one geographical area to another. Starch is mainly produced from maize in the USA (98% of American production), from cassava in Asia and from various crops in the EU (maize, wheat, starch potatoes, peas, barley, oats etc.). Maize is by far the most important source of starch in the world, as represented in Figure 6. It is worth noting that the USA produces some wheat starch, but at an insignificant level compared to maize starch. Part of the production from the rest of the world comes from tubers, mainly cassava. (Duval *et al*., 2010)[46].The raw materials in rice starch manufacture are rice and broken rice.

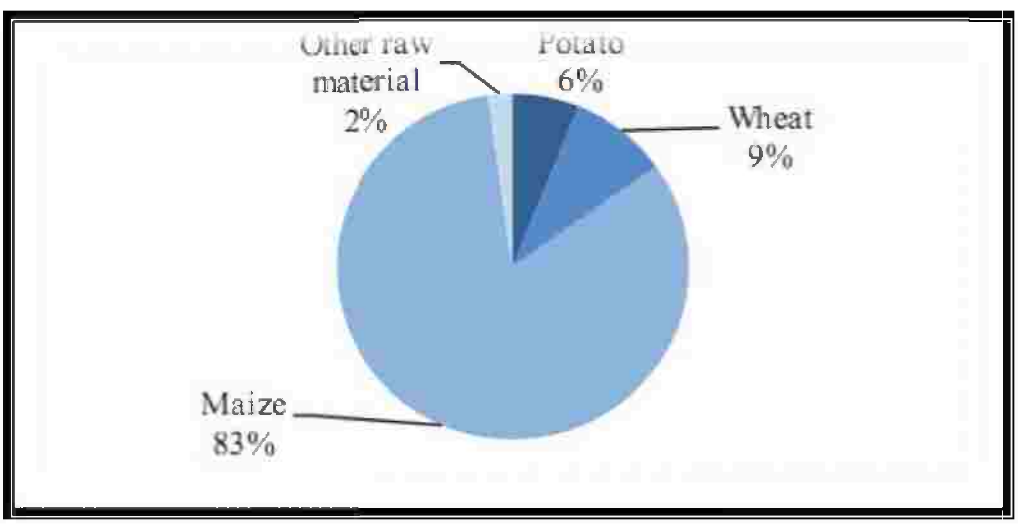

Figure 6: World market for starch by raw materials, 2005 (Agrosynergie, 2010) [47]

2.6.1. Rice

Two different species of rice are cultivated: *Oryza sativa* and *Oryza glaberrima*, and there are around 22 wild species. *Oryza sativa* originated in the wet tropic of Asia, but is now cultivated around the world, whereas *Oryza glaberrima* has been cultivated in West Africa for the last 3500 years. Rice accounts for 29% of the world's total cereal production, and is comparable to the production of wheat and corn. Cultivation is concentrated in the developing countries, mainly around East and Middle Asia, where 91% of the total world production (Rosell and Marco, 2008) [48]. The amounts of global Rice Paddy Production and Area are shown in Figure 7 (FAO, 2013)[49].

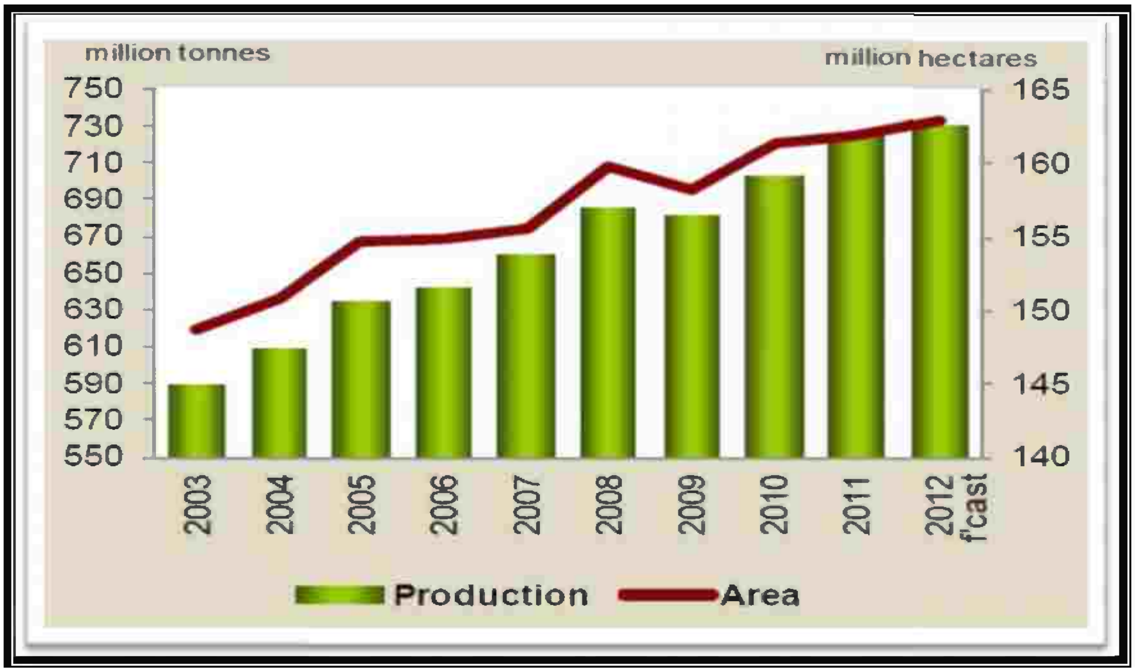

Figure 7: Global Rice Paddy Production and Area (FAO, 2013)[49].

2.6.1.1. Structure of rice grain

The rice grain consists of two distinct parts, the outer protective cover called the husk or hull, which is not suitable for human consumption, and the edible portion of the grain called the rice caryopsis or fruit, which comprises the brown rice. Figure 8 represents the structure of the mature rice grain. Brown rice consists of the bran, which comprises the outer layers of the caryopsis along with the embryo, and the endosperm. However, in rice milling, the bran, and the inner layer of the grain (sub aleurone) plus a small part of the starchy endosperm, called the polish, are not separated and therefore they are named as bran. The removal of the polish yields common white rice. The hull constitutes about 18-20% of the grain weight and its function is related to protection against insect infestation and rapid changes in moisture content of the grain the grain. The bran portion of the rice accounts for 5-8% of the brown rice (Antunes, 2002) [50]

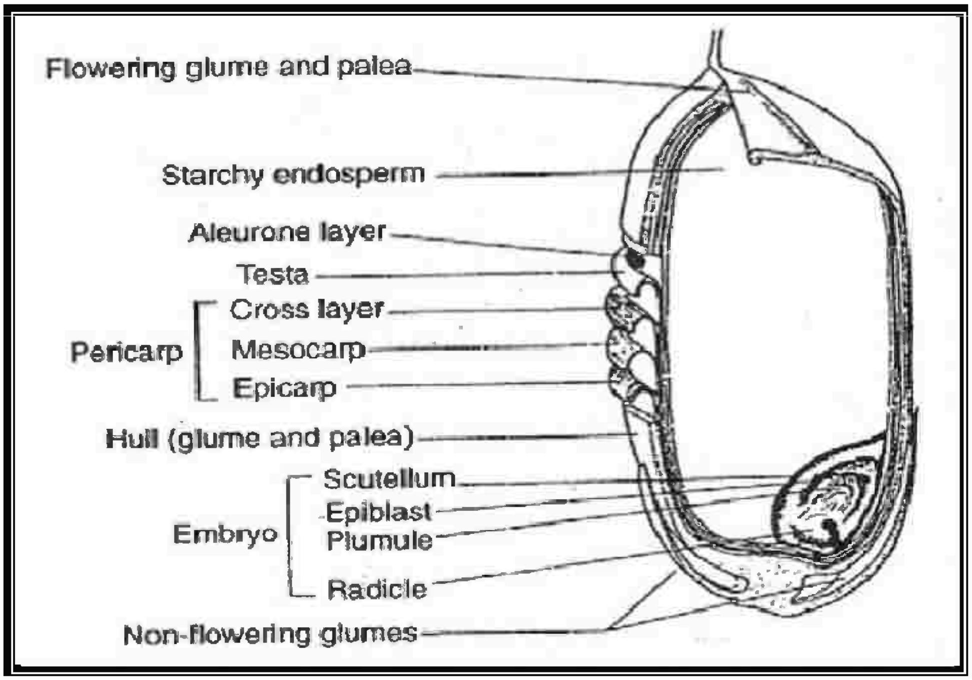

Figure 8: Structure of rice grain (Antunes, 2002) [50]

2.6.1.2. Rice Classification

Many varieties of rice are produced throughout the world. It has been estimated that there are approximately 7000 known varieties of rice. There are only two major species of cultivated rice: *Oryza sativa*, or Asian rice, and *Oryza glaberrima*, or African rice. Rice is also classified in three grain (kernel) types: short, medium, and long -grain. Grain size and shape are usually the first criteria of rice quality that breeders consider when developing new varieties for commercial production. Indica varieties tend to have longer grains while japonica types are generally shorter and rounder. The longer grain types are usually associated with higher amylose content, higher gelatinization temperature and dry fluffy cooking properties, while the typical short grain japonica types are moist and sticky when cooked. Classification of grain types is based on length to width ratios of rice kernels, the length to width ratios of the paddy (rough rice), brown and milled kernel of the long, medium, and short grain are given in Tables 3-4 (Cruz and Khush, 2000; Calpe, 2006) [51, 52].

Table 3: Rice size classification

Scale	Size category	Length in mm
1	very long	> 7.5
2	Long	6.61 - 7
3	Medium	5.51 – 6.60
4	Short	< 5.50

Source: (Cruz and Khush, 2000) [51]

Table 4: Rice shape classification

Scale	Shape category	Length / Width ratio
1	Slender	> 3.0
2	Medium	2.1 – 3.0
3	Bold	< 2.0

Source: (Cruz and Khush, 2000) [(51)]

2.6.1.3. Chemical composition of different rice varieties

Lai (2001) [(53)] studied two commercial rice flour GT Indian and GT Japonica. He found that the amylase, moisture, ash and fats contents were 30.68 and 18.52%, 12.47 and 14.0%, 0.36 and 0.53% and 0.22 and 0, 24%, respectively.

Onwulata *et al*. (2001) [(54)] found that the rice flour had carbohydrates, proteins, fats, ash and moisture content in amounts of 80, 5.71, 1.45, 0.6 and 12.0% respectively.

GuJral *et al*. (2003) [(55)] reported that the rice flour had moisture, ash and protein contents of 12.8, 0.57 and 8.83%, respectively.

Lovis (2003) [(56)] found that white rice flour had proteins, total lipids, carbohydrates, dietary fibers and water contents of 5.95, 1.42, 80.13, 2.4 and 11.89%, respectively.

GuJral and Cristina (2004) [(57)] found that the commercial rice flour had moisture, ash, proteins and amylase of 12.80, 0.57, 8.83 and 21.90%, respectively.

Sivaramakrishnan *et al*. (2004) [(58)] studied two types of (long and short grain) rice local market which contained moisture, protein, carbohydrate, fat and ash in the values 12.30 and 13.10%, 7.90 and 8.09%, 88.68 and 90.40%, 1.11 and 2.88% and 0.40 and 0.54%, respectively.

Takahashi *et al*. (2005) [(59)] reported that the moisture content of milled rice was 12.4% and its protein, lipids, and amylase contents were 6.2, 0.9 and 17.7%, respectively.

Cameron and wang (2005) [(60)] reported that the chemical composition of milled rice flour from different rice cultivars were ranged between 6.6 to 9.3%, 0.18 to 0.51%, 9.0 to 11.0% and 19.6 to 27.0% for crude protein, crude fats, moisture and amylase, respectively.

Heinemann *et al*. (2005) [(61)] reported that milled rice had 9.39 to 11.10% for moisture, 6.10 to 6.66% for proteins, 0.38 to 0.5% for crude fats and 0.32 to 0.47% for ash.

Anjum *et al*. (2007) [(62)] studied Chemical composition of fractions obtained from different rice varieties brown, white and polished rice. They reported that moisture content ranged from 10.93 to11.08%, crude protein content ranged from 6.11 to 7.23%, the ash content ranged from 0.54 to 1.42%, Fat content ranged from 0.73 to 2.13%, the fiber content ranged from 0.21 to 0.79% and Nitrogen free extract (NFE) value ranged from 72.21 to 81.19%.

Lozaridou *et al*. (2007) [63] found that the Egyptian rice flour had 15.1% moisture, 0.32% ash and 7.25% proteins.

Yadav *et al*. (2007) [64] found that chemical composition of milled rice from different rice cultivars ranged from 11.64 to 12.72% for moisture, 5.64 to 7.02% for proteins, 0.31 to 0.67% for ash, 0,54 to 0.82% for fats and 2,25 to 22.21% for amylase content.

Wanyo *et al*. (2009) [65] found that the rice flour had proteins 6.83%, fats 0.21%, carbohydrates 80.35%, ash 2.2%, fibers 0.61% and amylase 35.36%.

2.6.1.4. Nutritional content of rice

Hodzic *et al*. (2009) [66] reported that whole rice grains contain complex carbohydrates, resistant starch, dietary fibers, vitamins, minerals, microelements and polyphenols as well as antioxidant compounds which inhibit oxidational stress.

Umadevi *et al*. (2012) [67] reported that rice remains a staple food for the majority of the world's population. Rice is very nutritious. This important carbohydrate is the staple food for more than two-thirds of the world's population who rely on the nutritional benefits of rice has the following nutritional benefits:

Rice is a major source of energy and an important one of protein, as shown in Table 5. Rice also contains substantial amounts of zinc and niacin. On the other hand, it is low in calcium, iron, thiamine and riboflavin and has virtually no beta-carotene (Vitamin A). It is noteworthy that the highest the degree of polishing, the lowest the level of proteins, vitamins and minerals in the final product (Juliano, 1993) [68].

Table 5: Rice Nutrition Facts (per 100 g of raw rice)

Parameters	White rice	Brown rice
Moisture (water), g	10.20	11.20
Calories, kcal	361.00	362.00
Carbohydrates, g	82.00	77.00
Protein, g	6.00	7.40
Total Fat, g	0.80	2.40
Dietary Fiber, g	0.60	2.80
Calcium, mg	8.00	12.00
Phosphorous, mg	87.00	255.00
Potassium, mg	111.00	326.00
Sodium, mg	31.00	12.00
Vitamin B1(Thiamine) , mg	0.07	0.26
Vitamin B2 (Riboflavin), mg	0.02	0.04
Vitamin B3 (Niacin), mg	1.80	5.50

Source: (Puwastien *et al*., 1999) [69]

2.6.1.4.1. Carbohydrates

Juliano and Villareal (1993) [70] found that starch, the principal component of rice, consists of amylose and amylopectin and found that rice carbohydrate consists of starch and small portions of hemicelluloses, cellulose and free sugars. Also, Lumdubwong and Seib (2000) (71) reported that rice starch is used as an additive in various food and industrial products.

2.6.1.4.2. Proteins

The word "protein" is derived from the Greek word prôtos, meaning "primary" or "first rank of importance." Proteins are large molecules made up of amino acids bonded together by peptide linkages. They provide the essential amino acids, which are the initial materials for tissue synthesis and constituent of tissue protein. Thus, it was often referred to as the "currency" of protein nutrition and metabolism (Lau, 2005; Young, 2001) (72, 73).

Proteins are molecules containing one or more chains of amino acids of varying length. There are 20 naturally occurring amino acids. Each amino acid contains a central carbon atom (C) which has attached an amino group (NH_2), a carboxylic acid group (COOH), and a side-chain (R-group). The 20 standard amino acids differ only in their side-chains, which vary in size, structure and atomic composition. Amino acids within a protein are linked by peptide bonds. These form in a condensation reaction between the carboxyl group and the amino group of two amino acids through elimination of a water molecule (H_2O) as shown in Figure 9. A chain of amino acids linked by peptide bonds is referred to as a polypeptide (Voet and Voet, 2004; Rodnina *et al.*, 2007) (74, 75)

Animal proteins are more "biologically complete" than vegetable proteins with regards to their amino acid composition. The term "complete proteins" refers to foods that contain all the essential amino acids needed by the body, whereas, incomplete proteins refers to foods lacking in one or more essential amino acids (Shewry and Halford, 2001) (76).

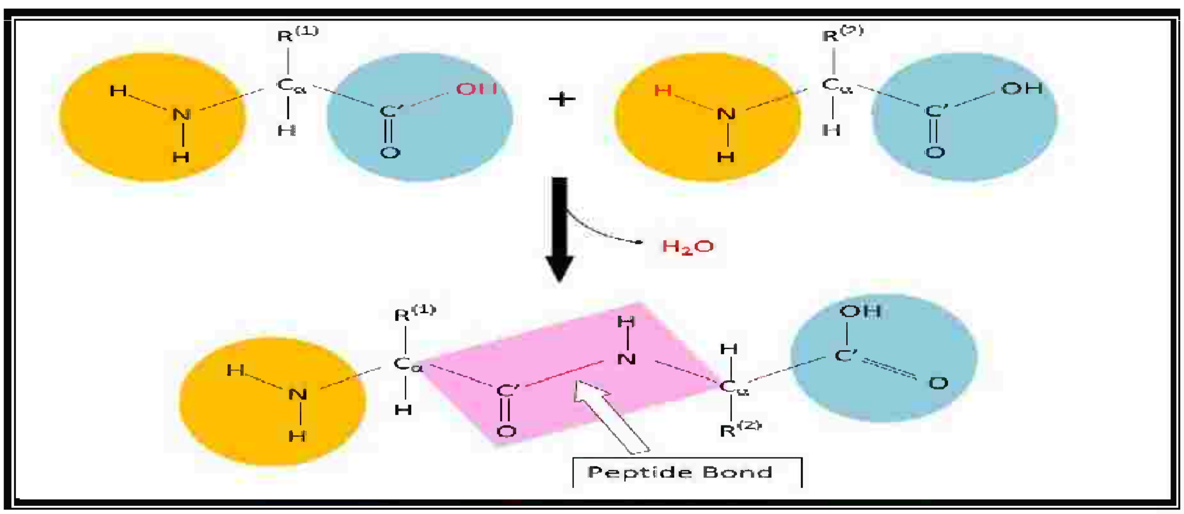

Figure (9): Condensation of two amino acids resulting in a dipeptide (Rodnina *et al.*, 2007)(75)

Proteins and starch are the two major components of rice, with approximately 8 and 80%, respectively. As shown in Table 6. Rice protein which accounts for 7–8 % (DB) in the milled rice kernel is classified into four types: alkali-soluble glutelins (80 %), water-soluble albumins (9–11 %), salt-soluble globulins (7–15 %) and alcohol-soluble prolamins (2–4 %) (Landers and Hamaker, 1994) (77).

Rice protein is valuable because it has unique hypoallergenic properties and ranks high in nutritive quality (rich in the essential amino acid lysine) among the cereal proteins (Marshall and Wordsworth 1994) [78]. It is evident that the amount of protein in rice is not very high but the quality of rice protein is far better than other cereals because it is more nutritious (about 4-5%) lysine which is higher than wheat, corn and sorghum (Janick, 2002) [79].

Protein content and amino acid composition varies in different fractions of rice kernel. The amino acid compositions of rice protein and their fractions are presented in Table 7 (Padhye and Salunkhe, 1979; Shih and Daiglehih, 2000) [80, 81].

Table (6): Protein contents of rice flour

	Protein content (%)	% of total protein
Rice flour	8.75	-
Albumin	0.38	4.45
Globulin	1.12	13.11
Glutelin	6.81	79.74
Prolamin	0.21	2.46

Source: (Padhye and Salunkhe, 1979) [80

Table (7) Amino acid composition of rice protein and their fractions

Amino acids	protein fraction*					Rice Isolate** (%)
	Albumin	Globulin	Prolamin	Glutelin	Rice Proteins (%)	
Aspartic acid	9.6	8.2	8.3	9.7	9.1	11.44
Threonine	5.1	2.7	1.3	3.0	3.5	4.17
Serine	4.7	7.1	5.1	5.4	4.8	9.49
Glutamic acid	12.0	16.4	19.9	16.9	16.9	17.82
Proline	5.9	4.2	5.5	6.0	5.4	6.67
Glycine	13.0	9.8	6.2	8.9	8.9	8.44
Alanine	11.1	8.1	9.5	7.9	8.6	6.73
Cysteine	2.2	0.9	Trace	1.7	0.9	------
Valine	6.8	7.1	7.0	6.8	6.7	2.34
Methionine	1.5	2.6	0.8	1.7	1.3	4.62
Leucine	3.3	4.0	4.4	4.1	4.6	4.55
Isoleucine	5.9	6.5	12.3	7.0	8.4	3.87
Tyrosine	2.8	2.4	6.4	3.7	3.7	2.07
Phenylalanine	2.6	3.7	4.4	4.1	4.0	4.55
Lysine	5.1	3.2	1.0	2.3	3.4	3.41
Histidine	2.2	2.2	1.7	2.1	2.2	2.05
Arginine	5.3	10.0	4.6	7.8	6.6	7.84
Tryptophan	1.0	0.9	1.6	1.0	1.1	-----
Hydroxyproline	----	----	-----	-----	------	-----

Source: * (Padhye and Salunkhe, 1979)[80] **(Shih and Daigle, 2000)[81]

2.6.1.4.3. Lipids

The fat or oil in rice grain is low (*i.e.*, 2–3%) and is concentrated in the germ and bran fractions. Rice lipids, which are predominantly triacylglycerides, are usually divided into free lipids and bound lipids where free lipids are ether-extractable whilst bound lipids are typically extracted with hot aqueous alcohols. The free lipids are adsorbed on the surface of starch granules whereas bound lipids (also referred to as starch lipids) are located inside starch granules where they are complexed with amylase (Wu *et al*., 1998; Zhout *et al*., 2002) [82, 83] .

Most of the rice lipids are neutral. They are triglycerides in which glycerol is esterified with three fatty acids, primarily oleic, linoleic, and palmitic. Besides triglycerides, free fatty acids, sterol, and diglycerides are also found in rice. Rice also contains lipid-conjugates like acylsterolglycoside and sterolglycoside, glycolipids, such as cerebroside, and phospholipids, such as phosphatidylcholine and phosphatidyl ethanolamine as in Table 8. (OECD Environment, 2004) [84].

Table (8): Composition of lipids in rice and its fractions

Property	Free lipids		Complexed lipids in non-Property glutinous starch	
	Milled	Polishing	Brown	Milled
Lipid Content (wt %)	0.8	10.8	0.6	0.5
Fatty Acid Composition (wt % of total)				
Palmitic (16:0)	33	23	46	45
Oleic (18:1)	21	35	12	11
Linoleic (18:2)	40	38	38	40
Others	6	4	4	4
Neutral lipids (% of total lipids)	82	87	28	26
Triglycerides	58	72	4	2
Free Fatty Acids	15	5	20	21
Glycolipids (% of total lipids)	8	5	19	16
Phospholipids (% of total lipids)	10	8	53	58
Phosphatidylcholine	9	3	4	4
Phosphatidylethanolamine	4	3	5	5
Lysophosphatidylcholine	2	<1	21	23
Lysophosphatidylethanolamine	1	<1	22	25

Source: (Juliano and Bechtel, 1985) [85]

2.6.1.4.4. Minerals

El-Hissewy *et al*. (2002) [86] reported that the minerals in different rice varieties in milled rice ranged between 0.98 to 2.75 for K, 0.33 to 0.61 for Mg, 6.03 to 6.35 for Zn, 2.25 to 11.50 for Fe and 1.35 to 8.78 for Mn calculated in mg/g.

Lovis (2003) [56] found that white rice flour contained 10, 0.35, 35, 76, 0.8, 0.13 and 1.2mg/100gm for Ca, Fe, Mg, K, Zn, Cu and Mn respectively.

Heinemann *et al*. (2005) [61] reported that the milled rice had 55.46, 15.06, 6.70, 2.09, 0.40, 0.53, 0.45 and 0.18 mg/100gm for K, Mg, Ca, Zn, Fe, Na, Mn and Cu, respectively.

Mineral content is greatly influenced by cultivation conditions including fertilization, and soil conditions. Among the inorganic elements contained in rice, silicon is dominant in paddy rice. In brown and milled rice, phosphorus is principal but comparable amounts of potassium, magnesium and silicon are also found. Contents of elements in rice milling and polishing are presented in Table 9.

Anjum *et al* (2007) [62] found that mineral contents were significantly higher in bran followed by polishing. Iron, zinc, manganese, copper contents ranged from 0.59 to 3.98 mg/100g, 1.12 to 4.69 mg/100g, 0.51 to 5.12 mg/100g, 0.28 to1.69 mg/100g respectively among different milling fractions. The mineral contents ranged from 1.57 to 1.94 mg/100g, 1.44 to 2.97 mg/100g, 1.57 to 2.33 mg/100g and 0.58 to 0.92 mg/100g among different varieties.

Table (9): Content of elements in rice milling and polishing

Element	Milled	Polishing
Macro elements (mg/g dry matter)		
Calcium	0.1 - 0.3	0.6 - 0.8
Magnesium	0.2 - 0.6	7 - 8
Phosphorus	0.9 - 1.7	12 - 26
Phytin Phosphorus	0.4 - 0.8	14 - 20
Potassium	0.8 - 1.5	8; 13
Silicon	0.1 - 0.5	1.3; 1.9
Sulfur	0.9	1.9
Microelements (µg/g dry matter)		
Copper	2 - 3	6 - 30
Iron	2 - 33	50 - 180
Manganese	7 - 20	…
Sodium	6 - 100	trace - 160
Zinc	7 - 27	20; 70

Source: (Juliano and Bechtel, 1985) [85].

2.6.1.4.5. Vitamins

Rice contains water-soluble vitamins including thiamine (B1), riboflavin (B2), pyridoxine (B6), nicotinic acid, inositol and cyanocobalamin (B12), and alpha-tocopherol (E). It does not contain significant amount of hydrophobic vitamins A and D. Vitamins mainly exist in the endosperm and bran layer, thus milled rice contains less vitamins compared with brown rice. Vitamin content in milled rice and polishing are presented in Table 10. (Juliano and Bechtel, 1985) [85]

Table (10): Vitamin content (µg/g dry matter) in milled and polishing rice

Vitamin	Milled	Polishing
Retinol (A)	0 - trace	0 – 0.9
Thiamine (B1)	0.2 - 1.1	3 - 19
Riboflavin (B2)	0.2-0.6	1.7-2.4
Niacin (nicotinic acid)	13-24	224-389
Pyridoxine (B6)	0.4-1.2	9-27
Pantothenic acid	3-7	26-56
Biotin	0.01 - 0.06	0.1 – 0.6
Inositol, total	90 - 110	3700; 3900
Choline, total	390 - 880	860 - 1250
p-Aminobenzoic acid	0.12 - 0.14	0.6
Folic Acid	0.03 - 0.04	0.9 – 0.8
Cyanocobalamin (B12)	0 - 0.0014	0 - 0.003
alpha-Tocopherol (E)	trace - 3	54 - 86

Source: (Juliano and Bechtel, 1985) [85]

2.6.1.4.6. Total phenol

Adam and liu (2002) [87] reported that the total phenolic content in rice was 5.56µmol/g grain.

Goffman and Bergman (2004) [88] studied 133 colored rice cultivars which analyzed for total phenolic content in whole grain. The accessions showed a large variation for total phenolic, ranging from 0.69 to 2.74 mg gallic acid equivalent (GAE) g^{-1} grain. The results suggested that bran color as the main factor effecting phenolic concentration in rice kernel. The red and purple bran groups can be found the higher phenolic concentration in rice kernel.

Tain *et al*. (2004)[89] found that total soluble phenolic acid contents in white, bran and germinated brown rice were 0,28, 2.17 and 1.45mg/100g flour, respectively. While total insoluble phenolic acid levels were 5.77, 18.47 and 24.78mg/100g flour, respectively.

Zhou *et al*. (2004)[90] determined total phenolic acid in three cultivars of fresh brown and milled rice then reported the phenolic profiles did not differ significantly between the three cultivates. The contents of phenolic acid were 415, 528 and 463mg/kg in brown Koshihikar, Kyeema and Doongara, respectively. While in milled rice were 86, 105 and 91mg/kg for Kpshihikar, Kyeema and Doongara, respectively.

Dykes and Rooney (2007) [91] reported that the whole grain cereals such as rice are good source of phenolics. Phenolic acids content in whole rice were 197 to 376mg/100gm.

Liu (2007) [92] showed that most grain phenolics were in bound form. Free phenolics contributed to 38% of the total in rice in contrast bound phenolics contributed to 62% in rice.

Liang *et al*. (2009) [93] reported that contents of total phenols of ethanolic and hot water extracts from phellinus fermented and phenolished rice were 4.38 and 1.31 mg/g, respectively.

Shen *et al*. (2009) [94] found that the total phenolic contents in white and brown rice were 151.8 and 197.5mg/100g, respectively.

2.6.2. Broken rice

Broken rice is one of the major by-products generated during milling process. "Broken kernels" means portions of kernels of which an estimated one-quarter or more of the original entire kernel has been broken off. (USDA) define a broken kernel as a kernel of rice that is less than three-fourths of a kernel for yield determination. Since the full-length grain is preferred form of rice, broken rice has typically half market value than that of head rice (USDA, 1994; Schramm, 2010)[95, 96]

FAO (2004) [97] used an arbitrary benchmark, with rice containing less than 20 percent of broken rice classified as "higher quality" and rice containing 20 percent or more brokens as "lower quality".

2.6.2.1. Egyptian standards for broken rice

Egyptian standard specifications for broken rice have been identified according to the decision of the Minister of Supply and Internal Trade, No. 330 of 1990. There are two types of rice long and short grain, Broken rice has several grades in each type of rice from Zero, 1, 2 and 3, these levels are different from each according to descending contain all of them less than a quarter of the grain, impurities, limestone and weed seeds. The Egyptian standard specifications for broken rice are presented in Table 11. (Ministry of supply and internal trade, 1990)[98]

Table (11): Egyptian standard specifications for broken rice

Specifications	Long grain				Short grain			
	Zero	No 1	No 2	No 3	Zero	No 1	No 2	No 3
grain less than a quarter not exceeding	10 %	20 %	30 %	50 %	5 %	15 %	25%	45 %
Yellow grain not exceeding	2 %	3 %	4 %	6 %	2 %	3 %	4 %	6 %
Foreign matter not exceeding	1.5%	2.5%	5 %	6 %	1.5%	2.5%	5 %	6 %

Source. (Ministry of supply and internal trade, 1990)[98]

2.6.2.2. Chemical composition of broken rice

Doma (1970) [99] studied the chemical composition of 3 grades of broken rice. He found that the high protein content are accompanied by relatively low starch content, no appreciable differences were observed between the grades of broken rice in the contents of ether extract; ash, reducing sugars, crude fiber and sodium chloride. These results are presented in Table 12.

Hertrampf and Piedad-Pascual (2000) [100] found that the chemical composition of broken rice is similar to that of whole, white rice, broken rice is relatively low in crude protein compared to rice bran. While crude protein, fat and crude fiber in broken rice are lower than in rice polishing,

Dahab (2006)[101] found that the broken rice flour had 7.68% protein, 0.7% fats, 0.27% crude fibers, 0.36% ash, 90.81% carbohydrates, 2.6% total dietary fibers, 0.89% soluble dietary fiber and 1.8% insoluble dietary fiber add to 1.3, 30, 0.38, 13.2, 0.24, 1.4 and 51.86 mg/100gm for Fe, Mg, Zn, Ca, Mn, Na and K respectively.

Table (12): Chemical composition of broken rice (grades zero, 1 and grade 2)

Constituents	Grade zero %Average on D.W	Grade 1 %Average on D.W	Grade 2 %Average on D.W
Crude protein	9.50	10.20	10.30
Ether extract	0.56	0.60	0.63
Ash	1.15	1.13	1.20
Reducing sugars	0.13	0.14	0.14
Non-reducing sugars	0.47	0.75	0.75
Starch	85.90	84.55	84.35
Pentosans	0.70	0.95	0.95
Crude fiber	1.05	1.10	1.10
Sodium chloride	0.48	0.60	0.60

- Moisture content: grade zero = 11.55% and grade one and two = 11.50%
  Source: (Doma, 1970) [99]

2.6.3. Water

A wet process is used to extract starch from the richest cereals (wheat, rice, corn). The nature of the effluents depends on the specific treatments used on the raw materials after common washing. When a wet technique is used to extract starch, the specific water consumption in different starch processing industries is shown in Table 13 which share to the water consumption in rice starch manufacture are 8-12m^3 /ton of rice or broken rice (Brault, 1991) [102].

Table (13): Water consumption in the starch processing industry

Raw materials / Water consumption	Potato	Maize	Rice	Wheat	Tapioca
m^3 Water / ton of Raw Material	14-23	9-10	8-12	20	5-10

Source: (Brault, 1991) [102]

2.7. Production process of rice starch

2.7.1. Alkali steep method for rice starch production

Because rice starch granules are very small and are surrounded by a water-insoluble protein matrix, it is necessary to soften the granules by chemical means first. Whistler and Paschall (1967) [(103)] share to "Orlando Jones", who operated a starch factory in London in 1840' patented a process which embodies the general principles of the processes now in use. The steps of ***Alkali Steep Method*** for rice starch production are as follows:

- The rice is steeped for 24 hr. in five times its weight of a solution of caustic soda, consisting of 1 part of caustic soda to 350 parts of water, to soften and partially disintegrate the kernels.
- The caustic soda solution is drawn off, and the kernels are then washed at least twice by vigorous stirring in an excess of water.
- The water is drawn off, and the rice is dried in bags.
- The dried rice is then ground in an attrition mill, and the finally ground flour is stirred into 10 times its quantity of caustic soda solution. Stirring greatly assists in accelerating the solubilization of the protein in the caustic solution.
- After 24h., the starch is resuspended in 20h.
- The major portion of the protein is contained in the supernatant caustic solution which is carefully siphoned off.
- The starch is resuspended in 20 times its quantity of water and vigorously stirred.
- The diluted starch milk is screened to separate whatever fiber is present.
- Washing, settling, and siphoning are repeated, and the refined starch milk is allowed to settle.
- The starch is then recovered and dewatered either by suction or pressure; the mass is then dried. The dried starch is crushed into coarse lumps, packaged, and shipped.

Throughout the years, variations have been introduced into the Jones alkali steep method.

Puchongkavarin *et al*. (2005) [(104)] used aqueous sodium hydroxide solution (NaOH) to isolate polished rice. The procedures of alkaline isolation are presented in Figure 10. Polished rice was steeped under gentle stirring in the initial phase in 0.1 M (0.4%, w/w) aqueous sodium hydroxide solution (NaOH) in the ratio of 1:2 for 18 h at 57C followed by wet milling of the grains sucked from the steeping liquor. To obtain the disintegrated rice slurry a colloid mill with a 150 mm milling slit was used. During milling a steady stream of tap water (approximately four times the rice weight) was admixed to prevent heating and gelatinisation of the starch. The slurry was then separated with a decanter to recover the solids. The resulting cake was re-suspended in the steeping solution (0.4% NaOH) and kept for 1 h. After steeping the liquor was separated finally by decanting and the cake was resuspended in water to accomplish further disintegration while passing through a screw-loop reactor at 1200 min. Following the final disintegration step the homogenised mixture was screened through 50 and 25 mm sieves, respectively, of a horizontal vibration sifter to remove fine fiber material. For washing the separated solids two subsequent decanter separations were applied. The cake was then re-suspended in tap water, neutralized with 10% H_2SO_4 and separated by decanting. It was washed additionally one time and decanted again. Finally, the cake was re-suspended in tap water and centrifuged at 6,856 x *g* for 2 min and 4,2756 x *g* for 5 min in a laboratory centrifuge with 2,800ml capacity. Following to centrifugation the supernatant was discarded and the dark tailing layer atop the starch carefully scraped away manually. The recovered cake was re-suspended in water and centrifuged again; purification was repeated four times in total. At the very end, the starch was dried at room temperature after spreading the cake over filter paper in thin layer. The separated tailings were discarded.

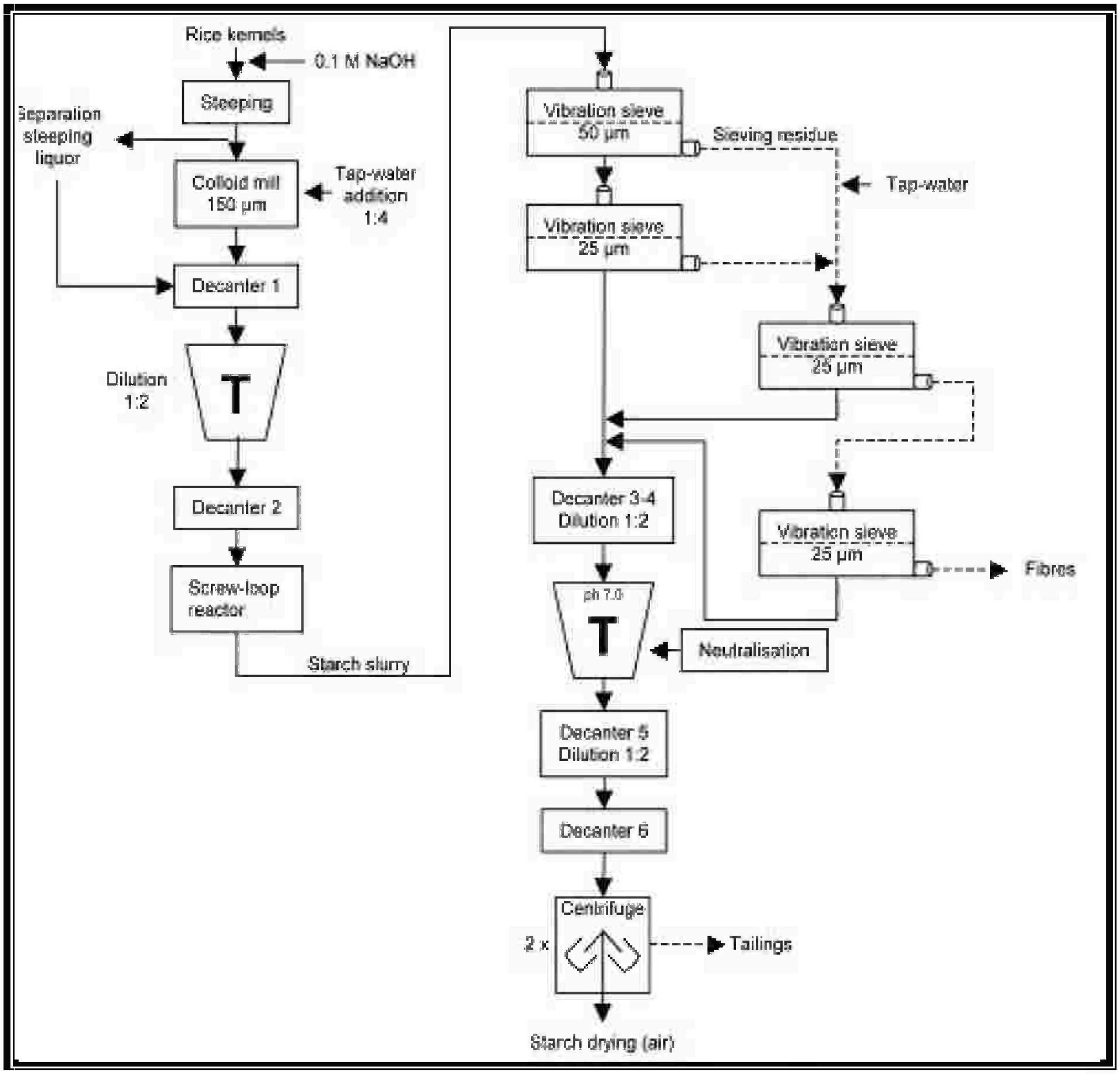

Figure (10): Alkali steep method for rice starch production (Puchongkavarin *et al.*, 2005) (104)

2.8. Characteristics of wastewater of rice starch industry

Doma (1970) [99] studied the wastewater in rice starch factory and shared to the chemical composition to the wastewater which discharged from steep and centrifuge processes. These results are represented in Table 14.

Table (14); Chemical composition of rice starch wastewater

parameter	Steeping liquor g /100ml	First centrifuge effluent g /100 ml
Crude protein	3.090	0.730
Ether extract	0.004	0.002
Ash	1.460	1.380
Reducing sugars	0.300	0.470
Non-reducing sugars	0.400	0.430
Starch	0.390	0.400
Pentosans	0.760	1.110
Crude fiber	0.790	0.650
Sodium chloride	0.180	0.150

Source: (Doma, 1970) [99]

2.9. Separation of protein from industrial wastewater

2.9.1. Isoelectric point and pKa values

Due to the presence of basic and acidic groups these zwitterions cause the amino acids to be amphoteric or ionisable in aqueous solutions (Cornell and Hoveling, 1998) [105].

Jaczynski (2008) [106] defined the isoelectric point (IEP) of a protein is a pH at which the protein maintains a zero net electrostatic charge. Therefore, the protein at its IEP exhibits the least solubility; however, as the pH is changed, the protein-water electrostatic interactions increase; and consequently, the protein becomes water soluble.

PKa is the acid-base dissociation constant which is the negative of the logarithm of the acid dissociation constant Ka. pKa values are solvent commonly expressed as in water or in dimethyl sulfoxide (DMSO) (Bordwell, 1988.)[107].

According to Cornell and Hoveling (1998) [105] the IEP can be calculated using pKa values. Cornell and Hoveling (1998) [105] provide glycine as an example in water, which they report to have an IEP value of 6.07 calculated from pKa values of 2.35 and 9.78. Note that IEP and pKa values provided by Heinau and Kirste (1994) [108] vary slightly to values provided by Cornell and Hoveling (1998) [105]

$$pH = \frac{PKa1 + PKa2}{2}$$

Where:

pKa1 and pKa 2 are respectively acidity constants for carboxyl and amino groups.

The same author added also that the isoelectric point is a state of hydrogen ion concentration where the ampholyte exists at the maximum degree at zwitterions and the positive charges on the zwitterions exactly balance the negative charges of the molecule.

Recently, isoelectric point is determined by titration curve of isolated protein after precipitation at various pH.

Shyur *et al.* (1988) (109) found that the fraction of rice proteins yielded is albumin, globulin, prolamin and glutelin in the proportions of 1.6: 9.6: 5.5: 83.3, respectively.

Ju *et al* (2006) (110) reported that the isoelectric points of albumin (pH 4.1), globulin (pH 4.3 and pH 7.9), and glutelin (pH 4.8), at which they were precipitated with 82.3 to 93.2% recovery efficiency.

Doma (1970) (99) reported that the isoelectric point to the rice steeping liquor is at pH 4.5 and the volume of protein precipitate is 70% from total protein.

The isoelectric precipitation method for protein isolate production includes solubilization of rice flour in an alkaline solution (pH 9-10, approximately 1.0N NaOH) and centrifugation to remove insoluble components. The solubilized proteins are precipitated by acidification of supernatant near the isoelectric point. The flocculated and precipitated proteins are collected by centrifugation or filtration (Swanson, 1990 ; Owusu-Ansah and McCurdy, 1991)(111, 112).

2.10. Separation of organic compounds from wastewater

Sedimentation, centrifugation, and filtration are mechanical separation process for the mixtures of solids and liquids, in practically all industrial sectors, including food, chemical, pharmaceutical, biotech, mineral, and environmental (Ford and Fleming, 2002) (113).

2.10.1 Sedimentation

Sedimentation, or clarification, is the process of letting suspended material settles by gravity. Suspended material may be particles, such as clay or silts, originally present in the source water. Sedimentation is accomplished by decreasing the velocity of the water being treated to a point below which the particles will no longer remain in suspension. When the velocity no longer supports the transport of the particles, gravity will remove them from the flow (Omelia, 1998) (114).

The settling behavior of suspended particulates in a gravitational field is affected by three factors: the particle size, the solid concentration, and the aggregation status of particles. In a dilute suspension, the settling solid behaves as individual particles and the process is regarded as particulate or free settling regime. Most clarifier operations fall into this regime. As the solid concentration increases, the suspended particles have more chances to approach each other closely and to form aggregates. Once the concentration reaches a level at which the suspended particles settle as a mass, the corresponding sedimentation is known as hindered or zone settling. In this regime, the settling behavior is related more to the solid concentration than to the particle size. As the solid concentration increases further, a settled bed of sediment mass is compressed by the overburden of sediment on top of it. Liquid is expressed from the lower sediment layers and flows upward through the sediment. This regime is termed compression regime. Sedimentation with the addition of chemical flocculants usually falls into this regime. A feed suspension in a thickener (or clarifier) can be operated in any regime. Therefore, the design of sedimentation equipment must consider all three regimes (Perry and Green, 1997; Schweitzer, 1997) [115, 116].

Most sedimentation tanks are divided into these separate zones: Inlet zone, Settling Zone, Sludge Zone and Outlet Zone, as shown in Figure (11).

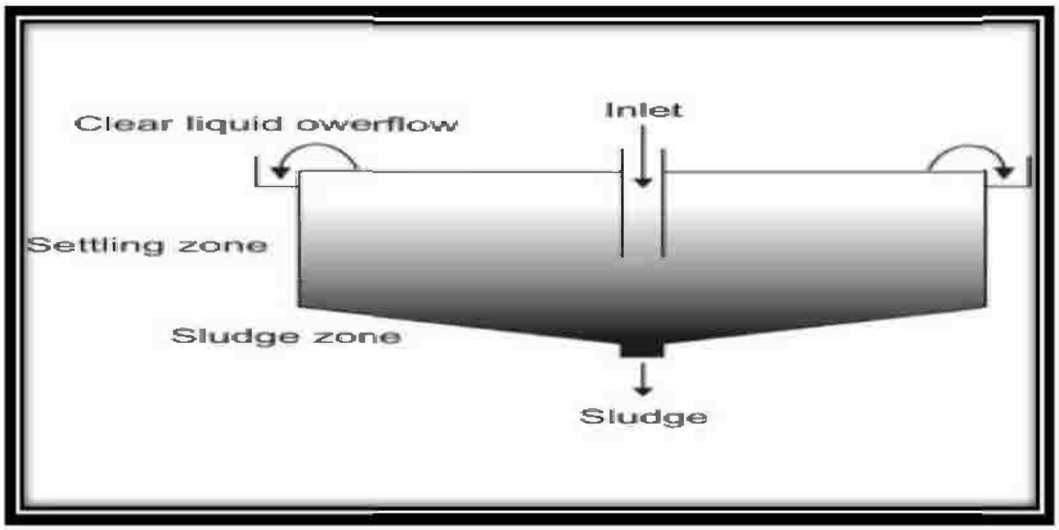

Figure (11): Sedimentation tank (Omelia, 1998) [114].

2.10.2. Centrifugation

Centrifugation involves solid-liquid separation using centrifugal forces to increase the settling velocity of suspended particles using either centrifuges or hydro cyclones. These separators function best with liquid slurries of 5 to 8 % solids, and are not as efficient when the solids content is lower (Sheffield *et al*., 2000) [117]

Metcalf and Eddy (1991) [118] stated that the centrifugation process is widely used in the industry in the purpose of separating liquids of different density, thickening slurries, or removing solids. The two basic types of centrifuges currently used are solid bowl and imperforate basket centrifuges.

Typically centrifuges consist of a horizontal or vertical cylinder which is continuously turned at high velocities. Centrifugal forces separate the liquid and solids onto the inside wall of the cylinder into two layers. An auger, which turns slightly faster than the cylinder, moves the solids to the conic part of the unit where they are discharged. The two types of centrifuge separators are centre sieves and decanters. Centre sieves, as shown in Figure 12, consist of an inclined revolving drum that is lined with a filter cloth. The slurry to be separated is pumped into the drum centre. The liquid leaves the drum through the filter cloth and the solids move by centrifugal force to the edge of the drum where they are removed separately. In the case of decanter centrifuges as in Figure 13, an auger, turning at a slightly higher speed than the cylinder in which it is contained, moves the slurry to the conic part, where it is discharged. Centrifuges are very effective at solids separation and can achieve relatively low moisture levels. The initial cost is high, however, and the energy requirement is also quite high in comparison to other systems (Fleming, 1986) [119].

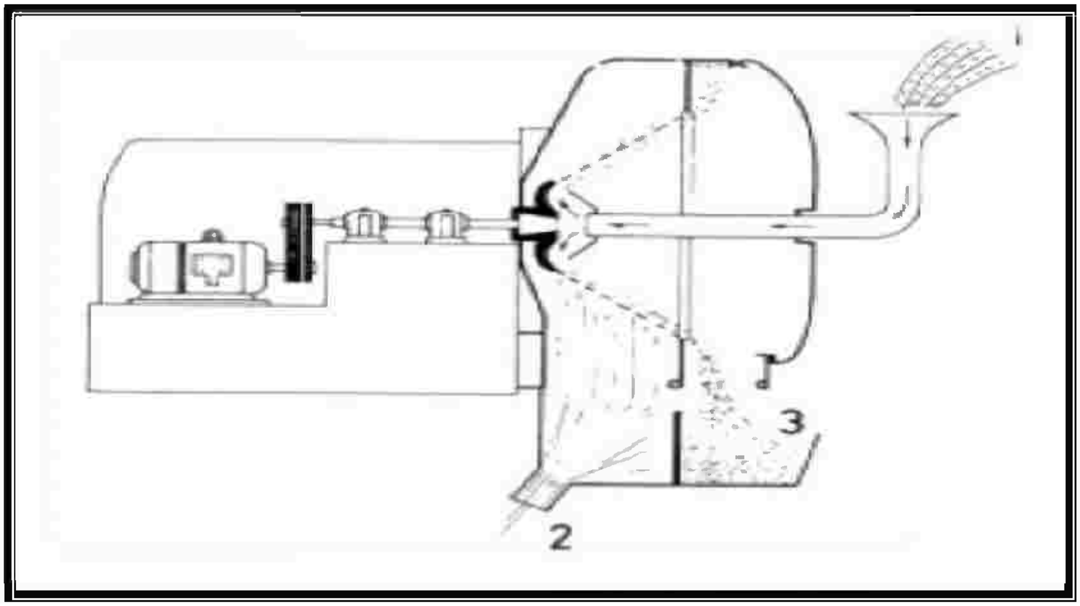

Figure (12): Centre sieve (Glerum *et al*., 1971)[120]
Where: 1. slurry, 2. liquids, 3 .solids

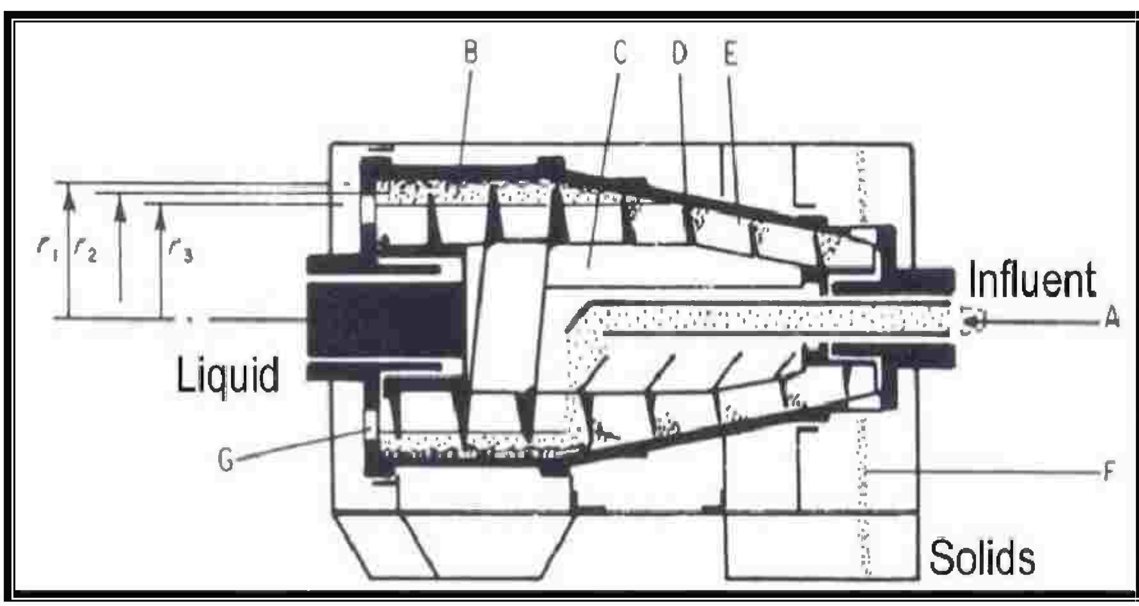

Figure (13): Schematic diagram of centrifuge decanter

A is wastewater inlet, **B** the bowl, **C** the screw, **D** the conical section, **E** the beach, **F** the solids outlet, **G** the level regulating discs, r_1, r_2 and r_3 are the inside radius, the radius of settled solids, and the liquid radius respectively (Sneath *et al*., 1988)[121]

Hydro cyclones are cone-shaped separators that have no moving parts and the necessary vortex motion is performed by the liquid itself as in Figure 14. They are configured so that when the slurry is pumped at an angle into the cylinder (near the top), it swirls at a high speed. The strong swirling motion accelerates the gravity settling of solid particles to the bottom of the cone while the liquid is discharged through a cylindrical tube fixed in the centre of the top.

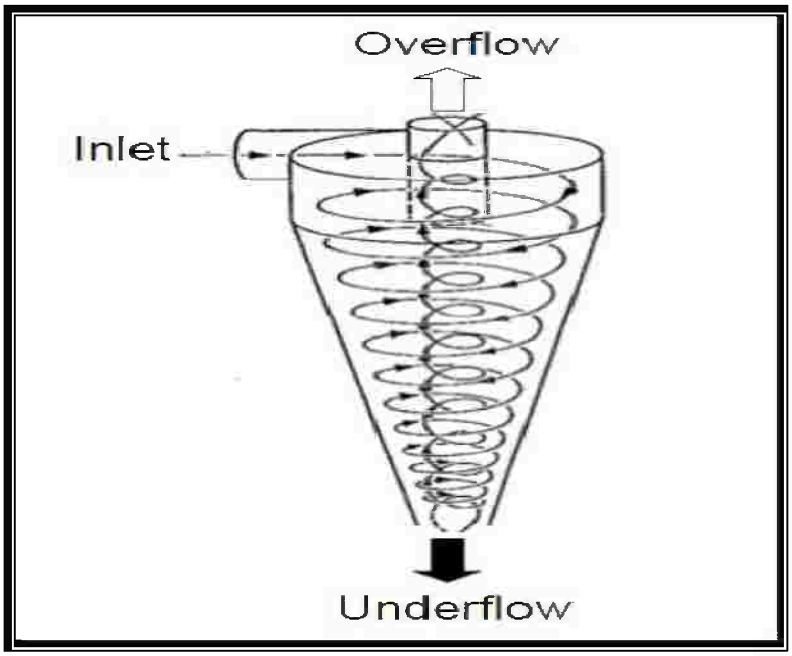

Figure (14): Hydro cyclone (Shutt *et al*., 1975) [122]

2.10.3. Filtration

Presses act as continuously-fed dewatering devices that involve the application of mechanical pressure to provide additional separation of the slurry. They are often used to remove additional water from the separated solids portion produced following screening or centrifugation. This physical separation process typically achieves a high level of dewatering and the pressed solid cake can be composted or used for refeeding. The three main types of mechanical filtration devices are roller, belt, and screw presses. A fourth type is the filter press (Ford and Fleming, 2002) [113].

2.10.3.1. Roller press

It has two concave screens and a series of brushes or rollers. The slurry to be separated is initially deposited onto the first screen and then moved across the two screens with brushes and squeezed by the rollers. The liquids are squeezed through and the solids remain on the screen.

2.10.3.2. Belt press

The belt press consists of a flat, woven, fabric belt that runs horizontally between rollers. The liquid is forced through the belt by the rollers and the solids are carried along on the belt and dropped into a solids collection chamber.

2.10.3.3. Screw press

The screw press is composed of a screw-type conveyor, in the centre, that forces the slurry through a tube and past a cylindrical screen. The screw conveys the solids retained on the screen to the end where the solids are discharged.

2.10.3.4. Filter press

This category of presses includes vacuum filters and chamber filter presses. The use of a filter cloth is incorporated into these designs for further solids removal (Ford and Fleming, 2002) [(113)].

a) The Vacuum Filter consists of a slow-revolving drum which is divided into a number of sections. It moves partly through the liquid to be treated. A filter cloth is fitted over the drum and one or more rollers. A vacuum is established in the sections moving through the liquid and the liquid is forced through the cloth. Solids are deposited on the cloth and removed by means of a scraper.

b) Chamber Filter Press separators may also be termed “pressure filters”. The slurry to be separated is introduced into the filtration chambers. These chambers are configured as plates which are forced against one another to de-water the slurry. The number of chambers or plates may vary and they are equipped with a filtering cloth.

2.11. Animal feed classification

Animal feed plays an important part in the food chain and has implications for the composition and quality of the livestock products (milk, meat and eggs) that people consume. The Food Standards Agency is responsible for drawing up the rules on the composition and marketing of animal feed. Feeds may be broadly classified as concentrates and roughages, depending on their composition. Concentrates are feeds that contain a high density of nutrients, usually low in crude fiber content (less than 18% of dry matter (DM)) and high in total digestible nutrients. Roughages are feeds with a low density of nutrients, with crude fiber content over 18% of DM, including most fresh and dried forages and fodders. Table 15 shows some of the most common concentrate and roughage feed used by commercial feedlots (FAO, 1983) [(123)].

Concentrate feeds are characterized by high energy and/or protein contents. Concentrate feeds mostly include various agro-industrial by-products and occasional surplus grains and grain by-products. The most common concentrate feeds include the following as in Table (15):

- Milling by-products (wheat bran, wheat short, wheat middling, rice bran)
- Oilseed cakes (noug cake, cottonseed cake, peanut cake, linseed cake, sesame cake, sunflower cake etc.)

- Molasses
- Whole cottonseed and
- Occasional surplus grain or grain damaged during processing.

Depending upon availability and price, modern finishing rations may contain about 75-95% concentrate and up to 90% of the energy may come from grain (Tolera, 2008)[124].

Table (15): Most common concentrate and roughage feeds used by commercial feedlots

Concentrates			Roughages
Energy	Protein	Energy & Protein	
• Grain (Maize, oats, barley, wheat and sorghum) • Molasses	• Oilseed cakes - Noug cake - Cottonseed cake - Sesame cake - Peanut cake - Sunflower cake - Linseed cake •Poultry litter •Brewers grain •Distillers grain	•Wheat bran •Wheat short •Wheat middling •Rice bran •Whole cottonseed •Bean bran •Lentil bran	•Grass hay •Cereal and pulse straws •Screenings (barley and wheat) •Hulls (barley, beans, lentils, beans, rice, cottonseed)

Source: (Tolera, 2008) [124]

2.11.1. By-products as animal feeds

Shortages of feed resources often impose major constraints on the development of animal production in the tropics and sub-tropics. However, from the production and processing of animals and plants for food production for humans and feed for animals many by-products and crop residues tend to accumulate and can be utilized as livestock feeds (Ensminger *et al*., 1990) [125].

Considerable quantities of crop residues and agro-industrial by-products (by-product feedstuffs, BPF) are generated every year in most developing countries in the tropics and sub-tropics. These are potentially suitable for the feeding of livestock. However, because of the lack of technical know-how they are lost or underutilized (Aregheore and Chimwano, 1991) [126].

By definition, a by-product feedstuff is a product that has value as an animal feed and is obtained during the harvesting or processing of a commodity in which human food or fibre is derived. By-product feedstuffs can be either of plant or animal origin (Fadel, 1999) [127].

Many by-products have a substantial potential value as animal feedstuff, though mostly in ruminant nutrition. The main reason is that ruminants have the unique ability to utilize fiber because of their rumen microbes. This means that cereals can largely be replaced by these by-products, thus reducing the competition between humans and animals for cereal products. (Boucqué and Fiems, 1988)[128]

Furthermore, recovering by-products for use as animal feed can benefit food processors by saving money while preventing pollution at the same time. Waste management and water quality have become key environmental and economical issues in agriculture and industry. Therefore offering by-products for use as animal feeds is an economically and environmentally sound way for food processors to reduce waste discharges and cut waste management costs, and also provide additional revenue to processors. Livestock farmers, as well, can save money if by-products provide a less expensive source of nutrients than traditional feeds provided they support acceptable animal performance. The use of by-products and wastes as sources of nutrients for domesticated animals has always reflected the ability of these animals to scavenge. From the early days of domestication those parts of plants that were unsuitable for human consumption because they were too fibrous or had an undesirable taste, or carried a high risk of infection, were given to animals which lived nearby. With the development of organised crop and animal production, the process of keeping animals on crop by-products developed to a considerable extent. In recent years, by-products are receiving increasing attention from livestock producers and nutritionists. The growth of the animal feed industry has allowed considerable use to be made of by-products and wastes, some of which, although containing potentially toxic components, can be safely included in compounded feeds in relatively low proportions (Wilkinson, 1988)[(129)].

2.12. The current situation of the animal feed gap in Egypt

There is a wide gap between the available feedstuffs and farm animals' requirements. The available local feedstuffs are not sufficient completely to cover the nutritional requirements of the Egyptian live stocks. Due to the annually increased prices of the available feed resources; nutritionists do their efforts to improve the nutritional values of such resources. In addition, they are looking for contribution to the available negligible agricultural by-products to provide additional marginal resources. Different treatment techniques and methods are being applied to improve the nutritional values of the additional roughage resources. Numerous attempts were being applied to modify such recycled wastes, using different chemical and biological methods to enrich its nutritional values to be recycled and recovered before being incorporated in animal feeds (Fouda, 2008)[(130)]

A feed is an important one of production inputs; its value is represented about 58.3% of the total value of agricultural production inputs in 2008. There are about 12 million animal units, the needs of those animal units of green feed were estimated about 39.8 million tons, about 9.6 million tons of straw, and about 15.9 million tons of concentrated feed. These needs were estimated at about 18.4 million tons of starch equivalent, and about 2.1 million tons of protein digested. The available quantity for consumption of feed was estimated about 64.8 million tons of green feed, about 9.2 million tons of straw, and about 5.1 million tons of concentrated feed. The available quantity for consumption were estimated at about 11.6 million tons of starch equivalent, and about 1.8 million tons of protein digested during the average period (2003- 2008), by estimating the feed balance in Egypt during the average period (2003-2008), the demand for feed derived from the demand for livestock products, as one of the important elements that enter in its production, increased demand for animal products leads to increase demand for feed, and noted that the availability of animal feed is less than the needs required for the animal sector, leading to the emergence of the feed gap in Egypt , a lack of feed supply than its demand leads to a lack of animal products supply, self-sufficiency ratio of red meat reached 67.2% in 2008. A lack of animal products could cover by import animal products or import the feed or increase of feed production (Moussa *et al*., 2011) [13].

2.13. The needs of livestock feed in Egypt

There are about 12 million units of animal in Egypt, (where is the head of a cow equivalent animal unit, also the head of the buffalo and camels equivalent 1.33 animal unit, the head of sheep and goats equivalent 0.21 animal unit), include about 4.6 million units of cows, about 5.2 million units of buffalo, about 1.1 million units of sheep, about 834 thousand units of goats, and about 194 thousand unit of camels. The requirements of the livestock feed about 39.8 million tons of green fodder, about 9.6 million tons of straw and about 15.9 million tons of concentrated feed. Buffalo occupies the first rank with ratio about 43.6% of the needs of feed, where its needs are estimated about 17.4 million tons of green fodder, about 4.2 million tons of straw, and about 6.9 million tons of concentrated feed. The cows occupies the second rank with ratio about 38.5% of the needs of feed, where their needs are estimated about 15.3 million tons of green fodder, about 3.7 million tons of straw, 6.1 million tons of concentrated feed. The sheep occupies the third rank with ratio about 9.3% of needs, where its needs is estimated about 3.7 million tons of green fodder, about 884 thousand tons of straw, and about 1.5 million tons of concentrated feed. The goats occupies the fourth rank with ratio about 7% of the fodder needs, its needs is estimated about 28 million tons of green fodder, about 667 thousand tons of straw, and 1.1 million tons of concentrated feed. Camels occupies the fifth rank with ratio about 1.6% of the feed needs, its requirements is estimated of green fodder around 646 thousand tons, about 155 thousand tons of straw, and about 258 thousand tons of concentrated feed. By transferring livestock needs in Egypt from all feed types, such as straw feed, green feed and concentrated feed, to the equivalent of starch and protein digested, these needs were estimated at about 18.4 million tons of starch equivalent, and about 2.1 million tons of digested protein. Tables 16, 17 present, the situation of the livestock in Egypt governorates, factories animal foddering in Egypt governorates and its production situation (full, actual and deactivated capacity) respectively (Moussa *et al*., 2011) [13].

Table (16) Livestock Num .and kinds at governorates year 2010

Governorates	Cows	Buffalos	Sheep	Goats
Alexandria	68493	58882	203321	112414
Behera	580382	391110	515509	269074
Gharbia	233007	245408	200086	116604
Kafr EL sheikh	286237	201731	187979	100384
Dakahlia	149828	164267	152792	65529
Damietta	61970	28160	28110	10166
Sharkia	529635	329171	355659	293866
Ismailia	46271	40570	49136	56544
Port said	34753	41825	9906	4370
Suez	15642	12129	3690	3891
Menoufia	239707	304069	188435	131636
Qalyoubia	101496	174825	88135	73377
Cairo	10136	7410	7525	2718
Helwan	43167	37153	34949	38142
6 - October	56049	88072	119077	123161
Giza	7123	7549	4947	3264
Beni suef	418056	179746	292749	242700
Fayoum	219574	143656	181022	160630
Menia	412707	357686	440252	435743
Assuit	290454	227601	317518	334346
Suhag	328851	319386	422424	430569
Qena	218368	224196	505797	446219
Luxor	39113	32480	105624	71922
Aswan	64570	84001	105141	82217
North sinai	2993	160	93975	119765
South sinai	255	205	14694	24918
Matruh	5595	814	384137	162717
New valley	151709	576	81496	97253
Red sea	783	812	158778	58729
Noubaria	111678	116592	306674	102157
Genral Total	4728721	3818236	5529529	4174986

Source: Ministry of Agriculture and Land Reclamation, Animal Wealth development sector (2011)[131]

Table (17): Factories animal foddering in Egypt governorates and its production capacity at year 2010

Governorates	Factories Num	Full capacity ton	Actual production ton	Deactivated capacity ton	Deactivated/ full capacity %
Alexandria	2	160000	777	159223	99.51
Behera	6	420600	81980	338620	80.51
Gharbia	13	1506800	160490	1346310	89.35
Kafr EL sheikh	22	618346	426246	192100	31.07
Dakahlia	15	413480	143570	269910	65.28
Damietta	1	43200	4963	38237	88.51
Sharkia	14	309402	103971	205431	66.40
Ismailia	3	14580	2845	11735	80.49
Port said	0	0	0	0	0
Suez	1	216000	53898	162102	75.05
Menoufia	5	48960	4147	44813	91.53
Qalyoubia	6	212528	12005	200523	94.35
Cairo	3	168000	45700	122300	72.80
Helwan	0	0	0	0	0
6 - October	8	94800	35205	59595	62.86
Giza	0	0	0	0	0
Beni suef	3	8700	1655	7045	80.98
Fayoum	6	96000	20594	75406	78.55
Menia	5	76000	64000	12000	15.79
Assuit	17	219510	119922	99588	45.37
Suhag	6	55500	41635	13865	24.98
Qena	2	57600	3641	53959	93.68
Luxor	1	11000	8000	3000	27.27
Aswan	2	3000	9	2991	99.70
North sinai	1	3000	900	2100	70.00
South sinai	0	0	0	0	0
Matruh	0	0	0	0	0
New valley	3	10000	57	9943	99.43
Red sea	0	0	0	0	0
Noubaria	4	144000	40130	103870	72.13
Genral Total	152	4911006	1376340	4174986	71.97

Source: - Ministry of Agriculture and Land Reclamation, Animal Wealth development sector (2011)[131]