Review

Critical issues in processing industrial agricultural raw materials

E.A. Salako and P.Z. Chuwang

Faculty of Agriculture, University of Abuja, Abuja.

Accepted 1 April, 2014

The fortunes of Nigeria’s agriculture have dwindled significantly from what it used to be more than 40 years ago. This paper seeks to discuss some critical matters in the production and utilization of agricultural raw materials so as to boost industrial applications and ensure safe and secure markets for farm produce. Environmental conditions for field production, post-harvest handling/processing and storage such as relative humidity, temperature, precipitation and sunlight should be considered as paramount. The inherent properties of these agricultural produce which are mainly crops must also be taken into account during production and processing. Details of critical moisture content, which, along with other physical and physiological properties determine the keeping qualities of the said farm produce, were discussed. The appropriate processing and handling of the agricultural products depend on their storage performance and durability/sensitivity. The products were also classified according to these qualities, namely durables, semi-durables and perishables. Important trade and developmental issues such as shelf life, maintaining standards and licensing as well as critical developmental infrastructure were considered.

Key words: Postharvest, processing, value addition, packaging, moisture content, Relative humidity.

INTRODUCTION

Nigeria is a highly endowed country agriculturally considering the existing favourable ecological conditions which can support the production of an enormous range of crops. During the late Colonial and early Post-colonial era, Nigeria was the world’s largest producer and exporter of palm kernel and palm oil, the second largest producer of cocoa as well as a leading producer and exporter of cotton, ground-nuts and rubber. This era has been rightly tagged the golden era of Nigeria’s agriculture because agriculture accounted for over 70% of Nigeria’s gross domestic product (GDP). The famous Malaysian oil palm industry owes its origin to Nigeria, unfortunately however, Nigeria is now a net importer of palm oil from Malaysia (Salako, 2011).

The situation is even more pathetic when we consider the fact that in 2010 Nigeria committed 25% of the N630bn used for the importation of food commodities to rice (CBN,2012) which can be profitably cultivated in almost all the ecologies of Nigeria. The Federal Government proposes to reduce the volume of food importation by 50% by 2015 (CBN, 2012). Fortunately rice is one of the five crops which government plans to promote over the next few years in order to achieve the targeted import reduction. The other crops in this promotion bracket are cassava, cotton, cocoa and sorghum.

Agricultural produce, especially crops, are usually harvested when they attain physiological maturity and when most of the desired portion(s) have accumulated all the nutrients and metabolites desired by the farmer or consumers. Sometime these produce are food stuff that may be consumed immediately without any further handling and processing but most often the crop output is in excess of the immediate consumption capacity. This calls for immediate and appropriate post-harvest handling, processing and storage. The desire by any nation to feed her population is important so that nation needs to support any process that will mitigate post-
harvest losses in crops in order to ensure steady supply of food and or raw materials hence the establishment of Nation Agricultural Produce Storage Research Institute at Ilorin.

The major challenge in the development of the agricultural sector is not very much the low production level of crops and livestock as it is the lack of value addition occasioned by poor postharvest handling and processing techniques of these produce given Nigeria’s level of technology and poverty. The level of value addition in Nigeria is about 35%, 3.2% and 1.8% that of South Africa, the United Kingdom and the United States respectively (Salako, 2011).

The focus of this paper is to contribute to the current efforts being made to return agriculture to its appropriate position in the economic profile of Nigeria by mainly highlighting the critical issues involved in the processing of agricultural produce (raw materials) for industrial applications and also for export. The post-harvest physiological processes taking place in crop produce may be known and the environmental factors influencing them may be fully known but a document which highlights the critical factors influencing the post-harvest handling and processing of crop produce into valuable raw materials for industrial purposes is not readily available. It is the object of this paper to fill this perceived gap in research through a review of existing literature in the relevant areas of knowledge.

Factors influencing the processing of agricultural raw materials (farm produce)

All agricultural products lend themselves to one or more form(s) of industrial application irrespective of whether the produce is of plant or animal origin. However, there are certain produce that have wider industrial applications and greater export potentials than others, considering the prevailing conditions and other extraneous factors.

Climatic factors influencing the processing of industrial agricultural raw materials

There are some climatic factors which are critical in the processing of industrial raw materials and to a large extent determine the success or failure of the production chain. These include:

Rainfall

Nigeria has a wide range of rainfall zones from the tropical equatorial rainfall of the coastal areas (>2000mm annually) to the dry sandy semi-desert in the north (<300mm per annum). The rainfall pattern determines the most appropriate processing method to be adopted for the produce. As a general rule the wetter areas with the annual rainfall over 1200mm may require electricity or other forms of power to facilitate artificial drying which is a fundamental aspect of post-harvest handling, processing and storage of farm produce.

Relative Humidity

Relative humidity (RH) like rainfall is critical in the handling, processing and storage of agricultural produce as it determines the keeping quality, structural integrity, texture, colour and taste of the produce (Wesolowski, 2008). There are critical levels of RH for processing and storage of products depending on the preferred form for utilization. The most important impact of RH is felt in the drying, which is the most critical operation in post-harvest processing of agricultural products (Ndukwu, 2009). It is a fact that all agricultural produce, whether crops or animal, are subjected to varying levels of dehydration naturally or artificially before further processing operations or storage.

Ambient Temperature

Ambient temperature and RH govern the drying rate, time and efficiency as well as the shelf life of the produce or raw material. There are critical temperature levels recommended for the various operations of the processing chains of the diverse range of agricultural produce and raw materials (Table 1).

Sunlight

Sunlight is a major source of energy available for drying of agricultural products to the rural peasant farmers who account for over 80% (Adewumi and Omoresho, 2002) of the nation’s entire agricultural output. It implies therefore that the intensity, duration and quality of sunlight should be of special interest to the agricultural stakeholders in Nigeria in order to ensure effective and efficient utilization of this important gift of nature and to avoid any harmful effects of excessive and injurious radiation. Sunlight is also the main basis for the construction of solar dryers that seek to tap and harness the sunlight (Brooker, 1992; Arinze et al, 1996).

PROPERTIES OF THE PRODUCT

The inherent properties of the product(s) that are critical in the processing of the agricultural outputs whether for consumption or for industrial purposes are as follows?

Moisture content (MC)

Plant products resulting from agricultural activities are
Table 1. Some critical internal and environmental factor affecting processing of farm produce.

<table>
<thead>
<tr>
<th>Product</th>
<th>RH (%)</th>
<th>Temp. (°C)</th>
<th>MC (%)</th>
<th>Physiological processes and undesirable changes in colour, taste, smell and by-products</th>
<th>Possible raw materials/ end products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yam</td>
<td>70</td>
<td>25</td>
<td>85</td>
<td>- Oxidation of anthocyanin - reddish brown to black</td>
<td>Chips, tubers - flour - instant pounded yams</td>
</tr>
<tr>
<td>Cassava</td>
<td>75</td>
<td>25</td>
<td>85</td>
<td>- Oxidation, hydrolysis, fermentation etc catalysed by enzymes. - Anthoganon and cyanogenic glycosides. - Greying and blackening - Microbial degradation</td>
<td>- Tubers - Chips - Starch - Garri, flour - Fu-fu etc</td>
</tr>
<tr>
<td>Milk</td>
<td>75</td>
<td>20-25</td>
<td>95</td>
<td>- Oxidation/reduction, hydrolysis, etc - Rancidity/fermentation of milk fats - Accumulation of microbes - Yellowing and greening of milk</td>
<td>- Fresh milk and powder - Butter, cheese, cream - Yogurt, etc</td>
</tr>
<tr>
<td>Grains and pulses</td>
<td>70</td>
<td>25-27</td>
<td>13-16</td>
<td>- Moulding due to fungal infestation - Loss of viability of seeds - Greying - Loss of weight</td>
<td>- Cereal grains like maize, sorghum, millet, acha, rice - Pulse - Soybeans, cowpea, ground nuts - Oils, flours, cakes etc</td>
</tr>
<tr>
<td>Fruits/vegetables</td>
<td>80-95</td>
<td>20-25</td>
<td>85-95</td>
<td>- Moisture loss, chilling injury in cold storage. - Respiration/ reduction - Accumulation of ethylene and premature ripening in fruits and softening, colour change, rotting fermentation etc</td>
<td>- Fruits – Mango, guava, paw-paw, oranges (citrus) etc - Juices - Vegetables-carrots, onions, spinach, pumpkins, cabbage, tomato etc - Pastes, dried concentrates</td>
</tr>
</tbody>
</table>

Source: Salako and Chuwang 2012

harvested with some level of moisture which may be the essential structural constituents of the products or other extra structural additions that usually increases the volume of the harvest. Processing of agricultural raw materials for industrial purposes should be handled with care in order to get high quality end products and to extend the range of industrial application of these farm products. In view of this, the critical MC of the farm products need to be determined for the various stages of the post-harvest value chain in order to accurately assess their drying rates and the energy requirements for artificial drying (Earle 1983). The molecular attractions of water in the matrix of products are usually higher than in the free liquid state and the molecular properties of the various materials govern the MC of the product and the drying rates (Wesolowski, 2008; Ndukwu, 2009).

Colour, texture and other physical properties

There are physical properties such as colour, texture, density etc that are unique to a product and these determine the way the product is handled and whether these properties need to be maintained after processing or and how much if at all changes are required. Colour, the chemical attribute of reflecting certain wave lengths by substances under certain conditions has been traditionally used to monitor the quality and ascertain the true nature of the materials or products. A slight change in colour may indicate deterioration or loss of physical or chemical state or structural integrity of the substance or product and this may be due to physiological or microbial processes. To illustrate this we can refer to cassava where physiological deterioration is the first to appear and it is caused by rapid postharvest accumulation of phenols, especially scopoletin, which, in the presence of oxygen, forms blue, black, and brown pigments. Scopoletin can be detected by exposing roots to ultraviolet light (IITA, 2001; Wesby, 2002).

Deterioration starts 24 to 48 h after harvest at those places where mechanical damage has occurred. Symptoms include a white or coffee-coloured ring as a result of desiccation at the periphery of the pulp and some blue-black streaks, especially near the xylem (IITA, 2001). Physical appearance of the farm products, most especially texture, can also be an important measure of the overall quality and often determine their mode of handling and storage.
**Nutritional content and chemical properties**

Food products are mainly of agricultural origin and the need to maintain as much of their natural properties as possible cannot be overstressed. Different parts of the plant or animal products have different proximate analyses and depending on the product and utilization the products may deteriorate due to internal reactions among the constituent organic substances to produce certain undesirable and or toxic by-products (Westby, 2002, IITA, 2001).

**Durability and Keeping qualities**

Agricultural raw materials can be classified into several categories based on certain considerations but the durability of the product and the length of storage is the most important of these factors. The products classes are perishables, semi-durables, and durables. The perishables include fruits, vegetables and other horticultural crops. These perishables have very high moisture content and need to be consumed or processed in their fresh state. The semi durables may also contain high moisture content but they can be safely handled and stored in their natural state such as yams, Irish and sweet potatoes as well as palm kernels, shea butter etc. Those products that can be conveniently handled and stored without elaborate preservation measures are termed semi-durables. These are mainly cereal grains, dry pulses, and other products which have very low moisture content. (Abbe, 2003).

**PROCESSING OF INDUSTRIAL AGRICULTURAL RAW MATERIALS**

The processing of any type of raw material is critical in the subsequent utilization of such raw material for industrial purposes and ultimately the quality of the final product. In this presentation we cannot be able to give a comprehensive assessment of all the critical issues involved in the processing of such a very diverse range of raw material as the agricultural products. We may just use one or two examples in some major categories to highlight the major issues involved.

**Processing durables**

In this agricultural group we have the cereal grains such as sorghum, maize, millets, rice, ‘acha’ and with irrigation barley and wheat can be successfully produced in commercial quantities. The other products in this category include dry pulses and oil seeds which include soybeans, cowpea, common beans, bambara ground nuts, ground nuts, sunflower, sesame, etc. The key to the processing of these raw materials starts from the field. This is to ensure that a good and mature crop is harvested which is free of pests and disease damage or infestation and free of contamination. They should be harvested as soon as they are ready usually when the weather is dry. To illustrate this, maize harvested in the wet season is usually for immediate consumption but the surplus, which is of interest to us, extra cost of drying should be included and every effort should be made to prevent the mature cobs or grains from absorbing moisture from rainfall, dew and the atmosphere. Additional cost of bending the cobs downwards may be necessary to prevent moisture settling around the grains within the husk. This greatly reduces the possibility of mould contaminating the grains before harvest. Prompt harvesting and rapid drying to about 13 and 15% MC is advisable for grains generally. However they could be stored at a much lower MC but there is a very considerable cost of keeping the grains from absorbing moisture. Delayed harvest may not only lead to post harvest mould infestation but may also result in substantial losses due to insects and rodent damage as well as field shattering (soybeans and sesame).

The main task of processing is drying and cleaning of grains and the other dry seeds. Drying is best achieved at the farm level in view of the urgency of the operation and limited time frame, while the grain cleaning can be done at the factory or at the industrial level. It is also possible to accomplish the task of extracting oil from oilseeds and even some grains such as maize at the factory level. The oil, in this case, becomes the raw material. Irrespective of the industrial use of the raw materials, they should be kept away from contamination and moisture by using silos for grains.

**Processing semi durables**

These diverse groups of products that include cocoa, cassava, yam, ginger, sweet and Irish potatoes, share a common feature, that is, their relatively high MC, compared to grains and dry pulses, but their modes of processing are not similar. These products are of a very wide range of crops but they can be stored and handled conveniently without much preservation.

i. Cocoa beans are extracted, fermented and rapidly dried.

ii. Cassava is prone to undesirable changes resulting from physiological reactions hence they need to be processed within 24 hours of harvest to avoid deterioration. Peeling, flaking and drying must be done in order to maintain the colour, texture and other qualities. There are other advanced forms of post-harvest storage prior to industrial processing or before reaching export destination. Such practices include chipping/pelleting and
freezing, as well as application of paraffin wax on the harvested root (Westby, 2002)

iii. Ginger may be cured, dried and ground into powder for further industrial application

iv. Yam tubers should be produced without blemish but yams can be transformed into uncooked or cooked flour (‘amala’ and packaged pounded yams respectively).

**Processing perishables**

These are farm produce that need immediate preservation procedure (within 24 hours) in view of their relatively high MC and nutritional profile which is most likely to attract microorganisms and other animate pests. The management of these highly perishable products starts in the field because most often the microorganisms that cause deterioration namely *Erwinia carotovora* and mould fungus (*Rhizoctonia spp.*) are acquired in the field most especially poorly managed fields. Under this category of products belong horticultural crops like fruits and vegetables as well as animal products. They are marketed as soon as they are harvested and if they are to be used as industrial raw materials or for packaging they should be free from injuries and contamination by impurities and microbes. Pre-cooling should be done as the first step in temperature management to take care of the heat that the products absorb from the environment during harvesting or in the case of animal and fish products, the high body temperature of the animal. This pre-cooling is made possible with the aid of the necessary facilities and equipment which ensures that the operation is carried out rapidly (Bachmann and Earles, 2000). The following agronomic field practices need to be adopted to reduce microbial load in the products:

i. Avoid the application of raw dairy or chicken manure or slurries to fields where vegetables crops are grown

ii. Avoid the application of manure to fields immediately adjacent to fields where vegetables are grown

iii. Use clean equipment on fields with horticultural crops and sterilise tools and equipment after they have been used on such fields as in i and ii above

iv. Refrain from using dirty water for irrigating these crops, most especially water used by livestock.

v. Harvested products should never be collected on areas where birds roost.

Some of the horticultural products like carrots, onions, sweet corn, water melon and spinach can be iced to ensure safe keeping, but others like tomato, green beans, cucumber okra, lettuce and garlic can be damaged by ice. To prevent moisture loss, there is need to maintain 80%-90% relative humidity (RH) (Bachmann and Earles, 2000). Some fruits that produce ethylene should be managed so as to avoid rapid ripening and premature softening.

**CRITICAL PRODUCTION MATTERS**

Any business that wants to stand the test of time in the market must make quality control and standards a priority. In the raw material market, this is very important as there are competing suppliers of similar products (raw materials) to the same markets (industries). The overall quality of any industrial end product depends to a very large extent on the quality of the raw material.

**Shelf life**

The main factors that determine the length of time any raw material can remain viable are moisture content of the raw materials, the atmospheric relative humidity and temperature as well as incidences of pests and diseases. The shelf life of the raw materials can also play a major role in deciding the location of the industry and the volume of operation. As a rule raw materials that have very short life span like cassava tubers need to be processed immediately hence most cassava based industries are located in close proximity of the cassava fields (IITA, 2001). Some produce like yams, Irish potato and onions that tend to sprout in storage can be inhibited using safe level irradiation but this requires very expensive and sophisticated equipment.

**Packaging, Licensing and other standard regulations and trade issues**

There is need to package, register (license) and maintain some set standards in any production system so as to preserve the product, attract and maintain the market as well as minimise cost of haulage and preservation.

**Packaging of agricultural raw materials**

Due to the tendency of agricultural raw materials to be damaged in transit and storage, packaging should be done in order to achieve the following objectives-

a. Preservation of the product-The aim of this is to prevent mechanical and physical damage and to reduce the accumulation/loss of moisture or increase in temperature. Other objectives of agricultural packaging include elimination/minimizing microbial contamination and development. As well as maintenance of product quality.

b. Agricultural products, especially those with high MC, may be bruised in transit if they are allowed to move too freely as a result of bogus packaging. It is often
necessary to provide some sort of cushion to protect the product at the same time allow enough space for ventilation. In this respect protective accessories such as wooden crates are convenient for multiple packaging and stacking.

c. Packaging should be neat, portable and appealing to the eye in order to attract clients. Fully and semi-processed products like oil, flour, honey and mushroom should be packaged in such a way as to warrant immediate consumption and display. The shape and colour of the package as well as labeling need to be attractive, concise and provide detailed production information like dates of production, expiration, source of product etc.

d. Appropriate but not unduly expensive packaging should be used for the products in order to minimise production cost and enhance the competitive advantage of the product in the market. In considering packaging, the producer should be able to strike a balance between preservation/safety of products on the one hand and cost of production on the other hand.

e. To adapt to the product, the following are available

i. Jute bags for grains
ii. Corrugated fibreboard for horticultural products
iii. Wooden crates-fruits, tubers, bulbs etc
iv. Plastic crates- the same as in iii above
v. Plastic bottles – for liquid and powdery products
vi. Plastic bags- Traps moisture and keep products (mushroom) fresh. When used for ginger, perforations required for ventilation
vii. Punnets are mini-packs made of light cardboards and fitted into trays where delicate products are kept to minimise friction and bruising.
ix. Packaging lining and padding are placed on the inner surfaces of packages to provide cushion and prevent bruising and deformation of delicate products such as fruits. Care should be taken to allow for ventilation.

Product licensing

Products are usually licensed to secure the marketing rights for the producer. The product ought to meet the specifications required by the consumers, who in this case, are the industries. These specifications form the minimum standards which differ according to product(s). The Federal Produce Inspection Service (FPIS) and some other standard/quality control agencies have guidelines on the criteria for licensing and minimum standards. Some of the criteria include, among other things, the following:

i. Length and strength of fibres like cotton lint and kenaf bark
ii. Level or intensity disease and pest infestation
iii. Microbial load in the products
iv. Concentration of the toxins and other undesirable substances eg aflatoxins, ochratoxins, deoxynivalenol, zearalenone, mycotoxins and fumonisins. There is usually a safe limit of these toxins in the products (IITA, 2001).
v. Acceptable moisture content (MC)
vi. Freedom from stones, pebbles, weed seeds dust and other impurities
vii. Level of maturity of products- immature products are termed low quality products
viii. Levels of irradiation for products that are preserved with radio-active materials.

Critical development issues

Critical development issues include power supply, infrastructure, level of technology etc. The processing, preservation and storage of products which require machinery or certain infrastructure that must be powered by electricity may be seriously hampered. This is due to the power problem in Nigeria and level of technical development that may place some restrictions on the application of technology in the processing of agricultural products into viable raw materials. There are other critical matters like financing, securing market, documentation etc that play major roles in the entire process of raw material processing from the field to the factory.

SUMMARY AND CONCLUSION

Production of high quality agricultural raw materials starts from the field through adopting recommended agronomic and other field practices that will ensure mature and disease/pest-free products. A sound knowledge of the internal properties and environmental conditions that control the production and storage of these raw materials is necessary for the success of the enterprise. The industrial potentials of the products and product specifications (standards) should be known and clearly stated on the packages. Agricultural raw materials have very wide range of industrial applications and fortunately Nigeria is blessed with these diverse crops and animal raw materials.

REFERENCES

Earle, R. L (1983). Unit Operation in Food Processing; Drying (Air-Drying) The New Zealand Institute of Food science and Technology Inc. wwwfirefox.org
IITA (2001). Post Harvest Deterioration of The Roots (of Cassava). On CIAT Homepage. (Ed) Teresa Sanchez
Websy, A. (2002). Cassava Utilization, Storage and small- Scaled Processing. Natural Resources Institute, University of Greenwich Chatham Maritime, Kent ME 4 TB, UK