# STUDY VISIT TO ICAR-CIRCOT

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# Briquetting and Pelleting Technologies and Practices

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## Introduction

Huge quantities of agro-residues are generated every year in many countries, but it is mostly disposed by burning in fields causing extensive environment pollution and soil degradation. The type and availability of agro-residues varies from place to place and country to country. The major residues, which are found in most of the countries are cotton stalks, bagasse, rice husk, saw dust, coffee husk, coir pith, jute sticks, groundnut shells, mustard stalks, etc. The utilisation of these residues is limited due to issues in collection, transportation, storage and handling. The direct burning of loose biomass in conventional grates results in very low thermal efficiency and widespread air pollution. In European countries, agro-residues are used effectively by densifying into briquettes and pellets. In several developed countries, the densification of agro-residues has not only solved the pollution problems but also provided a very important industrial/domestic energy resource. The biomass contributes about 70 % of the total energy generated from renewable resources in the European Union (EU). However, its usages are limited in developing and under developed countries.

**Figure 1: Burning of agricultural residues in fields**

In briquetting and pelleting processes, biomass is densified mostly in circular shapes. Briquettes of 90 mm diameter and pellets of 6, 8, 10 and 12 mm diameter are commonly manufactured in industries. Though, briquetting technologies are well developed and widely used commercially in developed countries, it is yet to get a strong foothold in many developing countries because of the technical constraints involved and the lack of knowledge to adapt the technology to suit local conditions. Overcoming the many operational problems associated with this technology and ensuring the quality of the raw material used are crucial factors in determining its commercial success.

At present two main high pressure technologies: ram or piston press and screw extrusion machines are used for briquetting. While the briquettes produced by a piston press are completely solid, screw press briquettes on the other hand have a concentric hole which gives better combustion characteristics due to a larger specific area. The screw press briquettes are also homogeneous and do not disintegrate easily. Having a high combustion rate, these can substitute for coal in most applications and in boilers. In India, more than 500 briquetting plants of 20 TPD capacity are running successfully for past 4-5 years. The biomass briquettes are mostly used in India for as boiler fuel (alternative to coal) in many industries. The recent successes in briquetting technology and the growing number of entrepreneurs, it is evidence that biomass briquetting has emerged as a promising option for the new entrepreneurs and other users of biomass in India.

The consumption of wood pellets has grown rapidly over the past 10 years, specially in developed countries. In Europe, pellets are mainly used for the production of electricity and residential heating. In the USA, most of the pellets are bagged and marketed for domestic purposes such as pellet stoves. Countries like Canada export wood pellets produced from sawdust and wood shavings to European countries (Sweden and Denmark). The worldwide pellet market (especially the EU) has a trend of persistent rise. The biomass pellet industry has gained a rapid momentum over the past decade. The USA and most of European countries are the largest markets for biomass pellets. United Sates of America and Sweden procure about 4 and 13 % of their energy, respectively, from biomass and Sweden is implementing initiatives to phase out nuclear plants, reduce fossil-fuel energy utilisation and enhance the use of bioenergy. In India, the pellet industry is gaining momentum in last 2-3 years. Over 250 small and large size pelleting plants are being operational in India. In India, biomass pellets are being used as boiler fuel as well as for preparation of snacks and cooking of meals, specially in roadside *dabhas,* restaurants, etc. The utilisation of pellets for cooking saves over 50% costs on fuel as compared to LPG gas price. The bulk density, durability, percentage of fines, dimensions, etc. are the major parameters that decide the quality of briquettes and pellets and their end usages. The list of commonly used agro-residues are mentioned in Table 1.

**Table 1: Properties of commonly used agro-residues for briquetting and Pelleting in India**

| S. No. | Agro-wastes | Type | VM, % | Ash % | Fixed C% | HHV, MJ/Kg | Pelleting/ Briquetting Potential |
|---|---|---|---|---|---|---|---|
| 1 | Cotton | Stem | 70.3 | 6.0 | 19.7 | 17.4 | Very Good |
| 2 | Soya | Stem | 76.9 | 6.6 | 16.4 | 16.4 | Good |
| 3 | Groundnut | Shell | 68.0 | 2.8 | 19.1 | 16.7 | Good |
| 4 | Sorghum | Stem | 69.4 | 6.4 | 18.82 | 16.6 | Good |
| 5 | Mustard | Stem | 71.2 | 5.2 | 19.38 | 17.3 | Good |
| 6 | Black gram | Stem | 68.2 | 3.5 | 23.4 | 16.3 | Good |

| S. No. | Agro-wastes | Type | VM, % | Ash % | Fixed C% | HHV, MJ/Kg | Pelleting/ Briquetting Potential |
|---|---|---|---|---|---|---|---|
| 7 | Wheat | Stem | 72.1 | 3.4 | 23.9 | 15.4 | Good |
| 8 | Bagasse | Stem | 75.8 | 4.2 | 20.1 | 18.1 | Very Good |
| 9 | Garden lawn | Leaves | 72.6 | 3.2 | 17.3 | 15.2 | Good |

The main purpose of this paper is to provide a comprehensive knowledge and understanding of briquetting and pelleting technologies commercially used in India. The paper covers the requirements of machinery, investment, land, manpower, etc. for establishment of a commercially viable briquetting and pelleting plant on effective uses of agricultural waste.

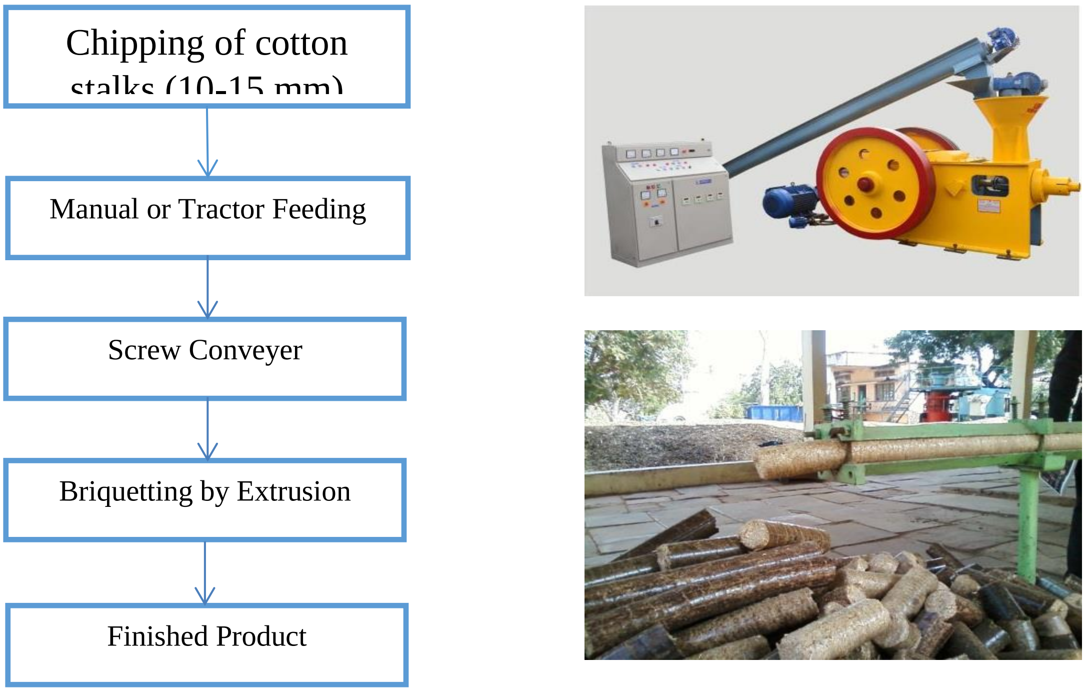


**Figure 1. Flow chart and machinery used in the**

## 1. Briquetting of Agricultural Waste

Briquetting is the process of densification of agro-residues to produce homogeneous, uniformly sized solid pieces of high bulk density, which can be conveniently used as a fuel. The softening of lignin due to generation of heat and its subsequent cooling during briquetting process causes natural binding of particles of cotton biomass into briquettes. The bulk density of cotton stalks can be enhanced to about 1000-1200 kg/m$^3$ from 100-120 kg/m$^3$ by briquetting process. The cotton stalk briquettes have been widely accepted worldwide as boiler fuel in many industries as it has very good heating value and less ash content. Ram or piston press and screw extrusion are two well-known high pressure technologies used for preparation of biomass briquettes. It is very simple and easy process to prepare cotton stalk briquettes, cotton stalks are shredded into small pieces of 10-15 mm and loosely fed into pressing machine, which converts it into briquettes.

The briquetting plants employ simple and low cost machinery, an investment of about Rs. 45 lakh (US $64,285) is required for establishment of a briquetting plant of 1.5 tonnes/h production capacity. The power requirement and energy consumption of a such briquetting plant is about 90 HP and 36 units, respectively. The production and maintenance cost of such plants is about Rs. 600/tonne (US $8.57/tonne). The profit of about Rs. 500/tonne (US $ 7.14/tonne) can be realised, if the biomass is procured at about Rs. 2500/tonne (US $ 35.7/tonne). The flow chart and piston press type machinery employed in briquetting process are represented in Fig. 1. The break of investment on plant, machinery and civil infrastructure for establishment of a briquetting plant is given in Table 2.

**Table 2. Feasibility for establishment of a briquetting plant in India**

| | | | |
|---|---|---|---|
| **A** | **Capital Investment (20 TPD Capacity)** | **INR in million** | **USD** |
| | Land and Building (Land Area: 2 acre; Building for Machinery: 150 Sq. M ; Material storage area:1000 Sq. M ; Office Building: 50 Sq. M) | **1.50** | **23,077** |
| | Plant and Equipment | **2.50** | **38,462** |
| | Auxiliary and Service Equipment (Chipper: 3 & Handling Tools) | **0.50** | **7,692** |
| | **Total investment** | **4.50** | **69,231** |
| **B** | **Operational Expenses** | | |
| | Raw Material Cost for 1 year (20 TPD for 300 days @ Rs. 2800 per tonne) | **16.80** | **258,462** |
| | Operational cost including repair and Maintenance and other charges (Rs. 600/tonne) for 1 year | **3.60** | **55,385** |
| **C** | Gross Annual Income (Rs. 4000/tonne) | **24.00** | **369,231** |
| | **Net annual income (Rs. 400/tonne)** | **2.40** | **36,923** |
| D | Payback period: **23 months** | Return on investment : **43.5%** | |

## Recommended briquette applications

Briquettes can be used in any appliances meant for burning wood or coal. However, certain changes in operating parameters especially regarding the distribution of primary and secondary air will have to be incorporated into the conversion. One should first understand the specific characteristics of briquetted biomass before taking steps to make changes in appliances. Briquettes have a density twice that of common fuel wood. Porosity is very low and, accordingly, char produced during combustion is denser than wood or biomass charcoal. The following are recommended uses of biomass briquettes:

| | |
|---|---|
| Boilers | : For steam generation |
| Food processing industries | : Distilleries, bakeries, canteens, restaurants and drying etc. |
| Textile process houses | : Dyeing, bleaching etc. |
| Agro-products | : Tobacco curing, tea drying, oil milling etc. |
| Clay products | : Brick kilns, tile making, pot firing etc. |
| Domestic | : Cooking and water heating |
| Gasification | : Fuels for gasifiers |
| Charcoal | : Suitable for making charcoal in kilns |

## 2. Pelleting of Agricultural Waste

Pelleting is a process of densification of biomass into homogenous, uniformly sized solid circular pieces of 6-12 mm diameter and 25-30 mm length. Pellets are easy to handle and burn easily as compared to briquettes because of its uniform shape, size and high energy density (IPCC, 2012). Wood pellets are utilized in many countries for cooking and heating applications (Peksa-Blanchard et al., 2007). The environmental concerns on cutting of woods for fuel applications have forced the wood pellet manufacturers to utilize alternative materials, specially agro-biomass for production of fuel pellets. The biomass based pellets are as good as wood pellets and are utilized as fuel for different applications such as heating, power generation, cooking, etc. The premium grade pellets of 600 kg/m$^3$ bulk density, 4000 kcal/kg heating value, 1-2% ash content, 98% durability index, etc. can be easily prepared from crop residues, specially cotton stalks.

**Table 3. Feasibility for establishment of a pelleting plant in India**

| **A** | **Capital Investment (3TPD Capacity)** | **INR in Mn.** | **USD** |
|---|---|---|---|
| | Land & Building: (Land Area: o.5 acre; Building for Machinery: 100 Sq. M ; Material storage area:500 Sq. M ; Office Building: 50 Sq. M) | **0.50** | **7,692** |
| | Plant and Equipment | **1.00** | **15,385** |
| | Auxiliary and Service Equipment (Chipper: 1 & Handling Tools) | **0.20** | **3,077** |
| | **Total investment** | **1.70** | **26,154** |
| **B** | **Operational Expenses** | | |
| | Raw Material for 1 year (3 TPD for 300 days @ Rs. 2800 per tonne) | **2.52** | **38,770** |
| | Operational cost including repair and Maintenance and other charges (Rs. 2950/tonne) for 1 year | **2.66** | **40,923** |
| **C** | **Gross Annual Income (Rs. 7500/tonne)** | **6.75** | **103,846** |
| | **Net annual income (Rs. 1000/tonne)** | **0.54** | **8,308** |
| D | Payback period: **33 months** Return on investment : **30.3%** | | |

The cotton stalk pellets have replaced LPG cylinders for cooking of foods in several restaurants in many parts of India as it costs about half the amount of commercial LPG and also provide smokeless flames similar to LPG flames. Pelletizing of cotton stalks is a multi-step process as described in Fig. 2. The break of investment on plant, machinery and civil infrastructure for establishment of a pelleting plant is given in Table 2.

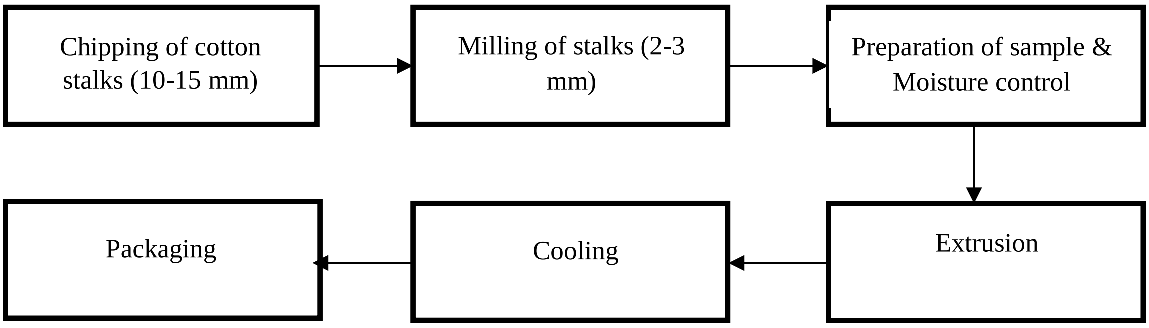


**Figure 2. Process of preparation of cotton stalk pellets**


**Figure 3. Small size pelletizer and 6 mm pellets prepared from milled cotton stalks**

The pelleting plants of 60-80 TPD capacity are commercially used for preparation of cotton stalk pellets. In addition, small scale pelletizer machines (3-5 TPD capacity) are also available in the market now-a-days that are intended to produce cotton stalk pellets (Fig. 3). A small capacity pellet plant can be established in Rs. 15 lakh (US $21428) while a large capacity plant require an investment of Rs. 3 crore (US $428,570).

## Procedure for set up a briquetting, pelleting plant

### Assessment of needs

Assess the demand in the surrounding areas, specially in small/medium scale process industries, brick kilns, large bakeries, or institutes and restaurant establishments which are either using coal or furnace oil. Original coal fired boilers/furnaces which were retrofitted to burn loose biomass are also potential users of briquettes and pellets, especially in those regions where pollution laws are rigidly enforced, or statutory regulations prevent them from using loose biomass.

**Availability of biomass**
Assess the quantity and type of biomass annually available within a reasonable (maximum 50 km) radius, the cost of transportation and the landed cost of raw material at site. Storage facilities either at site or at reasonably close locations should be assessed. The hazards of storing biomass for long periods and the potential loss of biomass due to winds or its biodegradation due to rains should be taken into account and incorporated into the cost of the raw material.

**Potential manufacturers**
Entrepreneurs who have either a captive market for briquettes and pellets or are generating their own biomass from agro processing industries or who can make briquetting, pelleting plants as ancillary units to large industries have brighter prospects as successful briquette/pellet manufacturers.

**Availability of infrastructure**
Sufficient land, power and managerial capabilities are a prerequisite for setting up these units.

# Degossypolization of cottonseed meal: A microbial method to produce new protein source for non-ruminants feed

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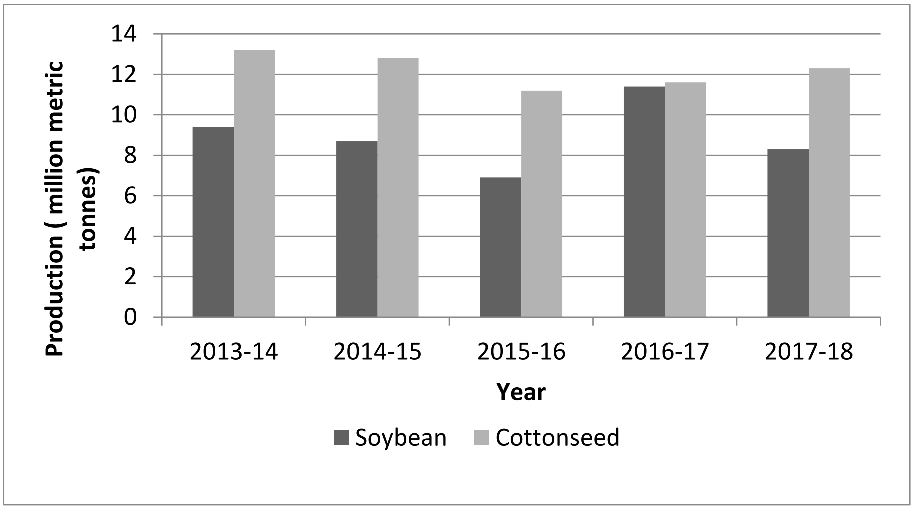
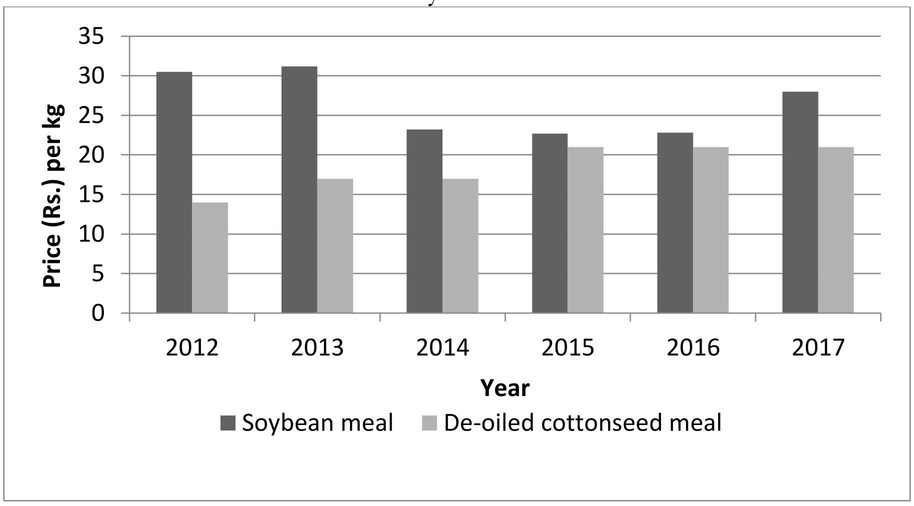
## Introduction

The non-ruminants feed is a mixture of few ingredients and additives in proper proportion to meet animal's nutritional requirement. Feed provides protein, energy, minerals and vitamins. Protein feed ingredient represent 25 – 35% of total non-ruminant feed. Protein is one of the major cost involving factors in the feed ration. Among the vegetable protein sources, soybean has been preferred owing to its protein content and better digestibility. However due to increase in demand of soybean protein for human diet and its high cost, there is an immediate requirement to find out an alternative source of protein supplement in non- ruminant feed. The production of soybean and cottonseed and price of soybean meal and cottonseed meal in India for the last five years (2012-17) has been compared (Fig. 1 a and b). The production of cottonseed was higher than soybean and the price of cottonseed cake/meal (CSC) was lower than soybean meal. In the year 2017, the market price of soybean meal was Rs. 28 per kg while CSC rate was 21 per kg. The fluctuation in production and market price was observed more in soybean than cottonseed over the past several years.

In India, about 4 million tonnes of CSC are produced annually. CSC is rich in protein and well known feed for ruminants. CSC contains 20 to 25% protein, 30 to 35 % fibre and 3-4% ash. The protein content and amino-acid composition of CSC is at par with soybean meal. However, the use of CSC for non-ruminants feed is highly limited due to the presence of toxic compound called gossypol, low level of essential amino acid, lysine and high fibre content (Gadelha et al., 2014). Considering the stability in production and price, the degossypolized, nutritive enriched CSC could be a best alternative substitute to soybean for non-ruminants protein feed source.




a. Production of soybean and cottonseed




b. Price of soybean meal and de-oiled cottonseed meal

**Fig. 1 Comparison of production and price of soybean and cottonseed**

## ICAR-CIRCOT's Degossypolization process

Gossypol is a polyphenolic binaphthyl dialdelhyde, and yellow pigment present in entire cotton plant including its seed. Gossypol is present in two forms viz., free gossypol (FG) and bound gossypol (BG). The total gossypol constitutes FG and BG. FG is more toxic than BG. The BG is formed by reaction between gossypol and epsilon-amino groups from lysine and arginine and forms Schiff base (Kenar, 2006). Feeding diets containing gossypol to animals would cause negative effects such as growth depression, reproductive disease and intestinal and other internal organ abnormalities (Francis et al., 2001; Robinson et al., 2001). Microbial fermentation of gossypol detoxification is the best alternative among different gossypol detoxification methods, since fermentation process enhance the nutritional value of CSM (Atia and Rahim, 2009).

At ICAR-CIRCOT, a novel process was developed for gossypol reduction and nutritive quality enrichment in CSC using solid state fermentation. It involves simple steps such as chemical disinfection of cottonseed cake, culture addition, incubation and drying as shown in the fig. 2 and 3. The fermented CSC showed improved nutritive quality parameters. The free gossypol, bound gossypol, crude protein, crude fibre and lysine contents in initial and fermented CSC were (2200, 360 mg/kg), (2100, 770 mg/100g), (20, 33.5 %), (35, 25%) and (0.4, 0.8 %) respectively (Mageshwaran et al., 2017). The gossypol level in the fermented cake meets the standards as prescribed by food and drug administration and protein advisory group, USA. The feed conversion ratio was found to be effective in the treatment up to 40 % replacement of soybean meal with fermented CSC in the diet of both broilers and layers. The results were ascertained with large scale industrial trials taken up to six tonnes of CSC. Based on the outcome of the result, the technology was filed for a patent (1477/MUM/2014 dated 28-04-14). Other than poultry, the fermented cottonseed cake could be widely used as animal protein feed source for fishes, piggery etc. as shown in the Fig. 4

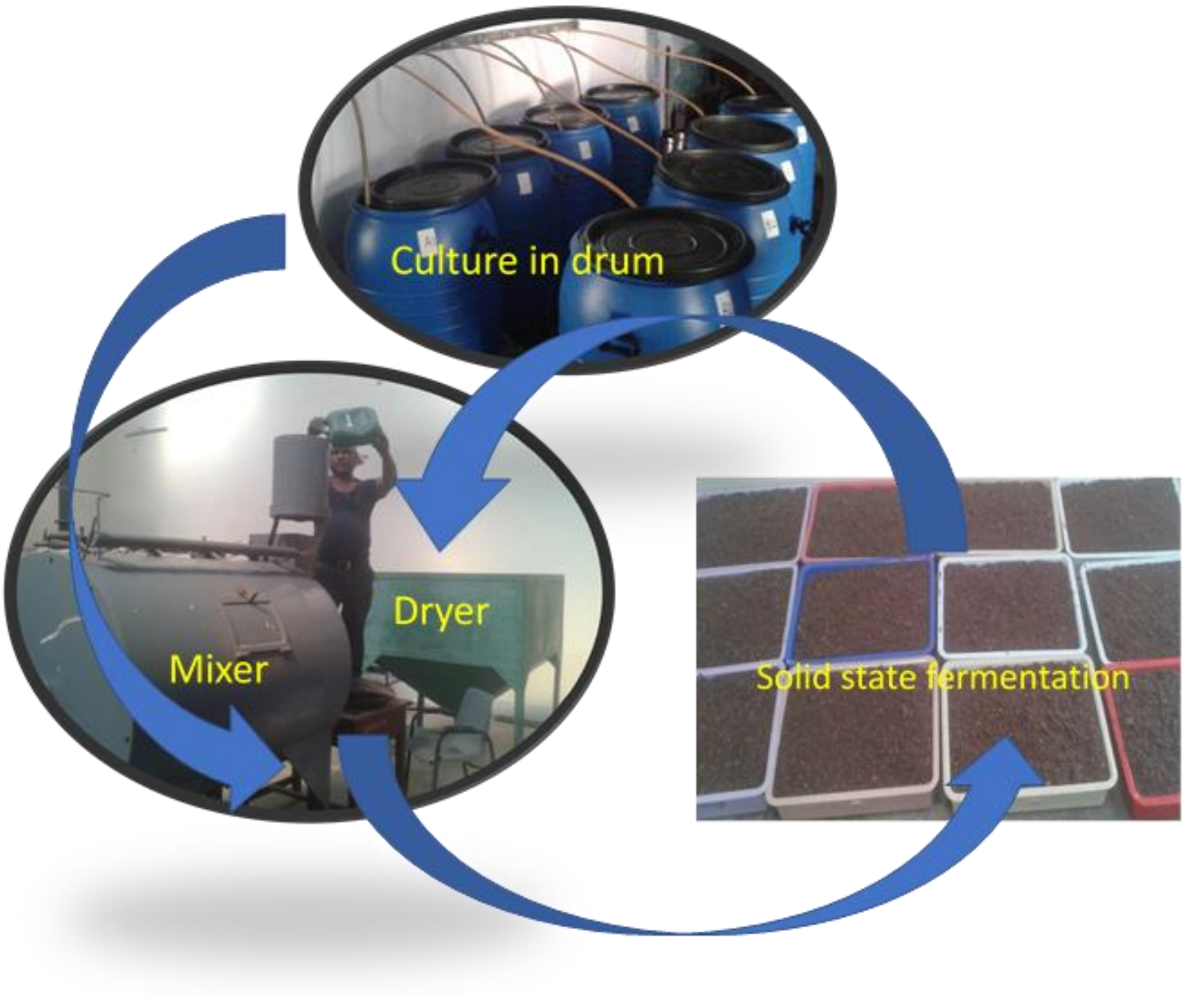



**Fig. 2 Microbial method for degossypolization of cottonseed cake**

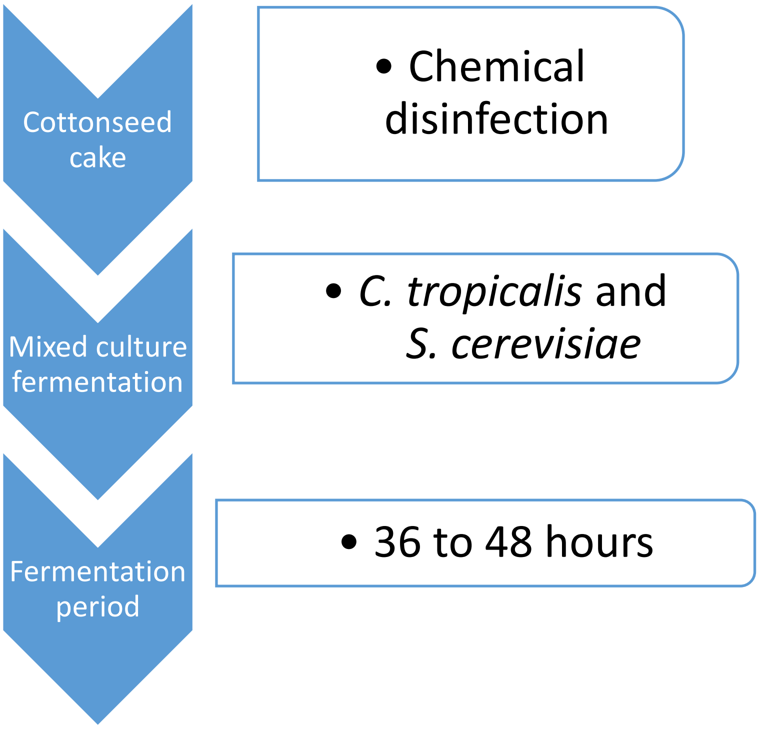



**Fig. 3 Degossypolization process**


**Fig. 4 Potential applications of degossypolized cottonseed cake in different feed sectors**

**Highlight of the process**

- 80 % free gossypol reduction
- 60% bound gossypol reduction
- Improved protein content
- Enriched lysine content
- Eco-friendly process
- Zero effluent discharge

**Technology transfer and commercialization**

The economic analysis showed the benefit cost ratio for production of degossypolized cottonseed cake was 1.25 considering the production and selling cost of degossypolized meal, Rs. 20,000/- and 25,000/- respectively. Thus, the degossypolized nutritive enriched cottonseed cake would be a potential protein source for non-ruminant feed industries. The detailed economic analysis of degossypolization technology is shown in Table 1. ICAR-CIRCOT has signed a MoU with a young entrepreneur, Mr. Irfan Ali, M/s Sana Agro-Industries pvt. Ltd., Raichur for transfer of technology on microbial process for gossypol reduction and nutritive quality improvement of cottonseed cake as per ICAR guidelines.

**Table 1 Economics of microbial process of degossypolization of cottonseed cake**

| | |
|---|---|
| Capital investment | Rs. 15.00 lakhs |
| Fermented cake production/year | 250 tonnes per year |
| Selling price | Rs. 25,000 per tonne |
| Products | Nutritive enriched CSC |
| Pay-back period | 1 year |
| Running cost | Rs. 44 lakhs per annum ( cost of raw material, microbial cultures, labour and over heads) |

**Conclusion**

ICAR-CIRCOT has developed a novel microbial process for production of degossypolized CSC for its use in non-ruminants feed sectors. The fermented CSC had 80 and 60 percentages reduction in free and bound gossypol respectively. The protein and lysine content was enriched in fermented CSC. Thus, the fermented CSC could substitute soybean meal in the non-ruminants feed industries such as poultry, fisheries and piggeries. The substitution of soybean meal with fermented CSC would reduce the feed cost significantly and thus the animal feed industries cottonseed processors would be highly benefitted.

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# Technology on Oyster mushroom cultivation using cotton stalks

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## Introduction

Mushroom are the fleshy sporophores of fungi known to grow in nature on decaying cellulosic materials, dead wood, soil and manure pits. Majority of these fungi belong to the class Baidiomyctoina and a few to the class Ascomycotina. Edible fungi are classified under the order Agaricales and the families Agaricaceae, Polyporaceae and Pluteaeceae have been under commercial cultivation. The edible mushrooms are delicacy in food and form one of the choicest table dishes. They are rich in protein and an excellent source of vitamins and minerals. Most of the mushroom have very low starch content and can form an ideal food for diabetic patients. There are four major edible mushroom are cultivated on a commercial scale. They are, *Agaricus bisporus* (white button mushroom), *Volvariella* spp (tropical mushroom or paddy straw mushroom), *Lentinus edodes* (Japanese mushroom) and *Pleurotus* spp (Oyster mushroom).

Mushroom cultivation technology is very vital in the tackle against shortage of food, diminishing quality of human health and pollution of the environment, which human beings still face due to the continue increase of the world population, natural resource degradation and impacts from climate change (Oseni et al. 2012). India has favourable climate, comparatively abundant land, biomass and labor, the production and utilization of mushrooms in India can be adopted easily. Despite such versatile benefits, in India, the mushroom cultivation technology lacks in adoption. The reason being, there is lack of appreciation about the food and dietary importance of mushrooms, the monotonous traditional diets and the conservative eating habit of people. Therefore promoting technology transfer concerning to mushroom cultivation is urgently required world-wide.

## Oyster mushroom status – Global and India

Mushrooms are produced all over the world. Oyster mushroom is the third largest cultivated mushroom. Globally, China is the leading producer of mushrooms, contributes nearly 85% of the total world production of about a million tonnes. The other countries producing oyster mushrooms include Korea, Japan, Italy, Taiwan, Thailand and Philippines. The present production of oyster mushroom in India is around 1500 tonnes. Punjab is the leading mushroom growing state In India. The inhibiting factors for less production in India are low domestic demand, large export demand order and can be met only if a linkage is developed between producer, cooperatives and exporters.

With the growing awareness for nutritive and quality food by growing health conscious population, the demand for food including mushrooms is quickly rising and will continue to rise with increase in global population which will be 8.3 million by 2025 (Ambili and Nithya, 2014). In India, due to varied agro-climate and abundance of farm waste, different types of temperate, tropical and sub-tropical mushrooms can be cultivated throughout the country. In India, about 600 million tonnes of agricultural waste including fruit and vegetable residue, cotton stalks, coir dust, husk, dried leaves, coffee husk, which has potential to be recycled as substrate for mushroom cultivation leading to nutritious food. Therefore there is a great scope for mushroom cultivation in India because of cheap and easily available raw materials needed for this activity.

## Nutritional properties of Oyster mushroom and economic Importance

Oyster mushroom is very good food for human consumption. It is rich in Vitamin C and B complex and the protein content varies between 20 to 30 percent. It has most of the mineral salts required by the human body. The niacin content is about ten times higher than any other vegetables. The folic acid present in oyster mushrooms helps to cure anemia. It is suitable for people with hyper-tension, obesity and diabetes due to its low sodium: potassium ratio, starch, fat and calorific value. Alkaline ash and high fibre content makes them suitable for consumption for those having hyperacidity and constipation. The chemical composition of the fresh fruiting bodies of oyster mushroom, *Pleurotus ostreatus* indicates a large quantity of moisture (90.8%), whereas dry oyster mushrooms are rich in proteins (30.4%), fat (2.2%), carbohydrates (57.6%), fiber (8.7%) and ash (9.8%) and energy value of 345 kcal on 100 g dry weight basis; while vitamins such as thiamin (4.8 mg), riboflavin (4.7 mg) and niacin (108.7 mg), minerals like calcium (98 mg), phosphorus (476 mg), ferrous (8.5 mg) and sodium (61 mg) on 100 g dry weight basis, are also found present (Pandey & Ghosh, 1996).

## Factors influencing oyster mushroom cultivation

The factors that affect the fruiting body formation, yield and duration of oyster mushroom production includes type of mushroom, composition of culture media, substrates, particle size, pH, moisture, carbon to nitrogen ratio (C/N), levels of spawning, light, temperature, humidity, etc. (Satankar et al., 2018).

Oyster mushroom cultivation requires any annually available raw agricultural substrates while the cultivation of button mushroom requires sterilized composted substrates. Thus, the oyster mushroom cultivation is cheaper than other mushroom types and become a lucrative business in tropical and semi tropical regions where the plenty of annually available agricultural substrates are available. The most commonly used substrates for cultivation of oyster mushroom are paddy straw, rice bran, wheat straw, wheat bran, saw dust, corn straw, banana wastes, sugarcane baggase, soybean stalks, cotton stalks etc. The yield of mushroom varies with the type of substrate in which it grows. Biological efficiency (BE) (%) is calculated based on the ratio of the yield of oyster mushroom to the dry weight of residue used for cultivation. The BE of oyster mushroom is varied between 25 to 75 % based on the substrate used and other conditions prevailed during the cultivation.

The species of oyster mushroom also decides the yield and duration of cultivation. The commonly cultivated species of oyster mushroom are *P. ostreatus*, *P. sajor-caju*, *P. florida*, *P. cystidiosus*, *P. eryngii*, *P. pulmonaris* etc. The successful mushroom cultivation depends on the purity and quality of spawn. Spawn is an essential component of mushroom production and it has a big effect on the sporophores production. The grain spawn is universally used despite some developments have been made on the use of cheaper material as growth medium for spawn production in place of grains. One of the biggest challenges for mushroom growers is the availability of quality spawn for its cultivation. The mycelial growth of mushroom culture in grains takes quite long spell and a minimum fifteen days is required for spawn production. The results of the some of the workers showed that the addition of sugars in the spawn media would enhance the mycelial growth and substantially reduce the duration of spawn production.

## Marketing of Mushroom

Harvested mushroom need to be handled carefully and it should be kept at a place where provision of air circulation, for example in a basket. The mushroom should be protected from sunlight and high temperature. The price of mushroom depends on the quality of mushroom like fresh, healthy and clean mushroom will get better price. Harvested mushroom should be taken to the market without delay to maintain their quality and freshness or they should be stored in a refrigerator or processed.

## Processing and storage of oyster mushroom

The oyster mushroom is highly perishable commodity and its shelf life is very poor. Normally, the shelf life of oyster mushroom is three days. Spoilage during storage can be caused by bacteria and fungi within the mushrooms. Hence, they are either marketed soon after harvesting or preserved with special care such as storage under controlled environment. The processing is necessary for better shelf life of the mushroom. They should be cooled to storage temperature of 0-2$^0$C within the five hours of harvesting. Under short term storage, mushroom is kept at 8-10$^0$C in packed container wrapped in plastic film. The other methods to enhance the shelf life of mushroom are drying, pickling and canning.

## Rural Entrepreneurship in oyster mushroom cultivation

Low cost artificial substrate for oyster mushroom production holds some potential to create wealth and reduce poverty among small-scale farmers and improve nutritional status of households' members. Mushroom cultivation can help to generate income and employment, particularly for women and youth in developing countries. Mushrooms are relatively fast growing organisms, thus, mushroom cultivation as a short return agricultural business can be of immediate benefit to the community. Mushroom cultivation requires relatively little space; they can be stacked or hanged for its cultivation. The mushroom cultivation technology is very simple technique uses locally available agricultural residues and requires low investment and can be easily adopted by Women Self Help Group for rural entrepreneurship.

## Mushroom cultivation at GTC, ICAR-CIRCOT, Nagpur

ICAR-CIRCOT investigated the suitability of cotton stalks on production potential (growth performance and yield) of oyster mushroom. The implication of this study is to facilitate technology adoption of oyster mushroom cultivation using cotton stalks and thereby identify the feasibility of mushroom cultivation for the betterment of life of the local community.

At Ginning Training Center (GTC), ICAR-CIRCOT, Nagpur, oyster mushroom (*Pleurotus florida* and *Pleurotus ostreatus*) was cultivated on hot water treated cotton stalks of 3-4 cm length. The protocol for cultivation of oyster mushroom has been given as flowchart (Fig.1). The experiments were conducted for oyster mushroom cultivation in cotton stalks at GTC, Nagpur during June to September of the year 2016-18. The mushroom was cultivated by hanging bag technique at the mushroom cultivation facility at GTC, Nagpur (Fig. 2 a). The results showed 300 g of fresh oyster mushroom could be harvested from one kg of dry cotton stalks. The harvested oyster mushroom cultivated in cotton stalks has been shown in Fig. 2 b. The cropping period for cultivation of oyster mushroom in cotton stalks was thirty days. An average of two harvests was done per crop. Efforts were taken to diffuse this technology among the farmers of Vidarbha region of Maharashtra. About five hundred farmers including women farmers were given awareness and hands-on-training on oyster mushroom cultivation using cotton stalks (Fig. 2 c).

The average cost of production of one kg of fresh oyster mushroom is Rs. 50/- in which the major cost involved is spawn cost (Rs. 30/-). Two hundred g of spawn was used for the production of one kg of fresh mushroom. The yield of mushroom is mainly depends on the quality of the spawn used. The selling price of fresh oyster mushroom in the market ranges from Rs. 80 to 150/-. The selling price depends on marketing place, quality and other parameters. Thus, a farmer can earn a minimum of Rs. 30/- per kg of oyster mushroom produced. On an average, a famer can generate a minimum additional income of Rs. 6,000/- per acre by cultivation of oyster mushroom in cotton stalks generated from an acre of land. The initial investment required here is thatched house of 20 × 20 feet dimension which costs to Rs. 20,000/-. The payback period is two years within which the initial investment could be recovered (Mageshwaran et al., 2017).

Shredded/Chipped cotton stalks

↓

Soaking for overnight

↓

Decant the water and boil chipped cotton stalks at 80°C for 2 hours

↓

Decant the water, cool and place the cotton stalks in poly bags (30 × 60 cm) in layers of 2 inches to prepare mushroom bed

↓

Sprinkle mushroom spawn at the rate of 5 % between the layers of cotton stalks especially in the periphery region

↓

Tie the poly bag and make tiny holes randomly around the poly bag

↓

Place the poly bag in hanging rope or standing racks

**Fig. 1 Protocol for cultivation of oyster mushroom in cotton stalks**

**Note:** Temperature and Relative humidity required for oyster mushroom cultivation is: 25 – 30° C and 55 – 80 % respectively. Initially, for first twenty days, the mushroom bed was kept in dark room while for next ten days, poly bag was removed ventilation was given.

**a. Hanging bag technique for cultivation of oyster mushroom**

**b. Harvested fresh oyster mushroom**

**c. Hands-on-training on mushroom bed preparation using cotton stalks**

**Fig. 2 Oyster mushroom cultivation using cotton stalks**

## Conclusion

Mushroom cultivation technology is an economically viable for conversion of various ligno-cellulosic agro-wastes into a food source. This technology is very easy to adopt, requires low investment and can generate employment among the rural masses leading to improvement in social as well as economic life of rural people.

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# Absorbent Cotton Technology

*Dr. Ashok Kumar Bharimalla, Senior Scientist, ICAR-CIRCOT*

Absorbent Cotton consists of the new fibres or good quality new combers obtained from the seed coat of various species of the genus Gossypium Linn., cleaned, purified, bleached and carded. It does not contain any compensatory colouring matter.

## Description

White, well-carded fibres, average staple length not less than 10 mm, containing not more than traces of leaf residue, seed coat and other impurities, offers appreciable resistance when pulled, does not shed a significant quantity of dust when shaken gently, practically odourless.

**Absorbent cotton** is defined as "the cotton for surgical dressings, cosmetic purposes etc. made absorbent by removing natural wax". It is also known as surgical cotton or cotton wool. Due to its property of high fluid absorbency it is known as **Absorbent Cotton** among the masses. It is mainly used for medical purposes in hospitals, healthcare centers, dispensaries and nursing homes to absorb the body fluids. Apart from medical purposes absorbent cotton is also used for making conventional type of sanitary napkins or pads. Fairly good quality of absorbent cotton is also used for removing make-up and dirt at beauty parlours/salons. It is also used in business organizations and households for various purposes, as dressing material and also for padding of clothing items, quilts etc.

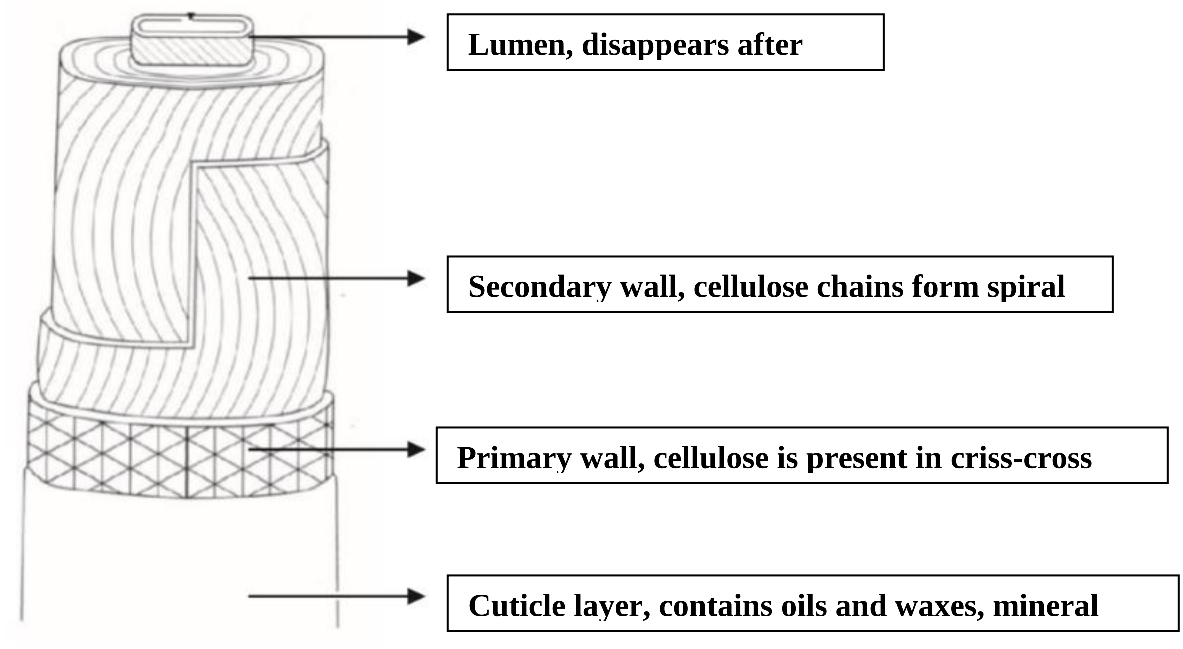
This hygiene product is not new to industry; but its growth witnessed a boom with the recent development in medical facilities, population growth and increased awareness about personal hygiene. A study by the global management consultants McKinsey predicted that India's healthcare industry will reach a market of USD 190 billion mark from 25 billion mark with in 2027. The report said that increasing health awareness among youth, metropolitan life style and increasing percentage of house hold expenditure on the health are the key reasons for this growth. This will increase the demand for absorbent cotton now and near future. Absorbent cotton is also used for making sanitary pads, cosmetic pads besides medical purposes. The absorbent cotton should be chemically inert, soft to give maximum protection and should not cause any irritation. Raw cotton fibre which is picked from the field is not absorbent and hydrophobic due to its inherent chemical nature. The raw cotton is processed by series of steps which make the cotton hydrophilic in character and free from external & internal impurities which can be used in surgical dressing and personal hygiene.

## Cotton fiber and its structure

The chemical composition of cotton varies according to the source and geographical conditions.

| Constituent | Cellulose | Protein | Pectin | Wax | Ash | Other substances |
|---|---|---|---|---|---|---|
| Percentage Weight On dry fiber | 88-94.0 | 1.2-1.9 | 0.7-1.2 | 0.4-0.6 | 0.8-1.4 | 1-1.7 |

Cotton fiber has fibrillar structure. Its morphology as illustrated schematically in the figure below exhibits three parts; primary wall, secondary wall and lumen. The primary wall has network of cellulose fibrils covered with an outer layer, or cuticle, of pectin, protein, mineral matter and wax. Pectin is the gummy substance which binds the cuticle layer with primary wall.




The non-cellulosic substances of cotton are usually located in the cuticle of the fiber. Cotton wax is found to present in the outer surface of the fiber. Wax content in finer cotton is generally higher than coarser cotton. This wax renders the fiber impermeable to water and aqueous solutions unless a wetting agent is used. The secondary wall constitutes the bulk of mature fiber and has fibrils of cellulose arranged spirally around the fiber axis.

### Requirement of properties to be improved for absorbent cotton

| Nature of Property | Raw Cotton | Requirement as per Standard* | Responsible substances |
|---|---|---|---|
| Ash Content | 1.2% | <0.5 % | Mineral Matter |
| Sinking Time | > 60 seconds | 10 seconds | cellulose |
| Water holding capacity | Practically Nil | > 23 grams of water/ Gram of cotton | cellulose |
| Water Soluble Substances | 1% | <0.5 % | Sugars |
| Whiteness | Yellowish White | - | Flavone |

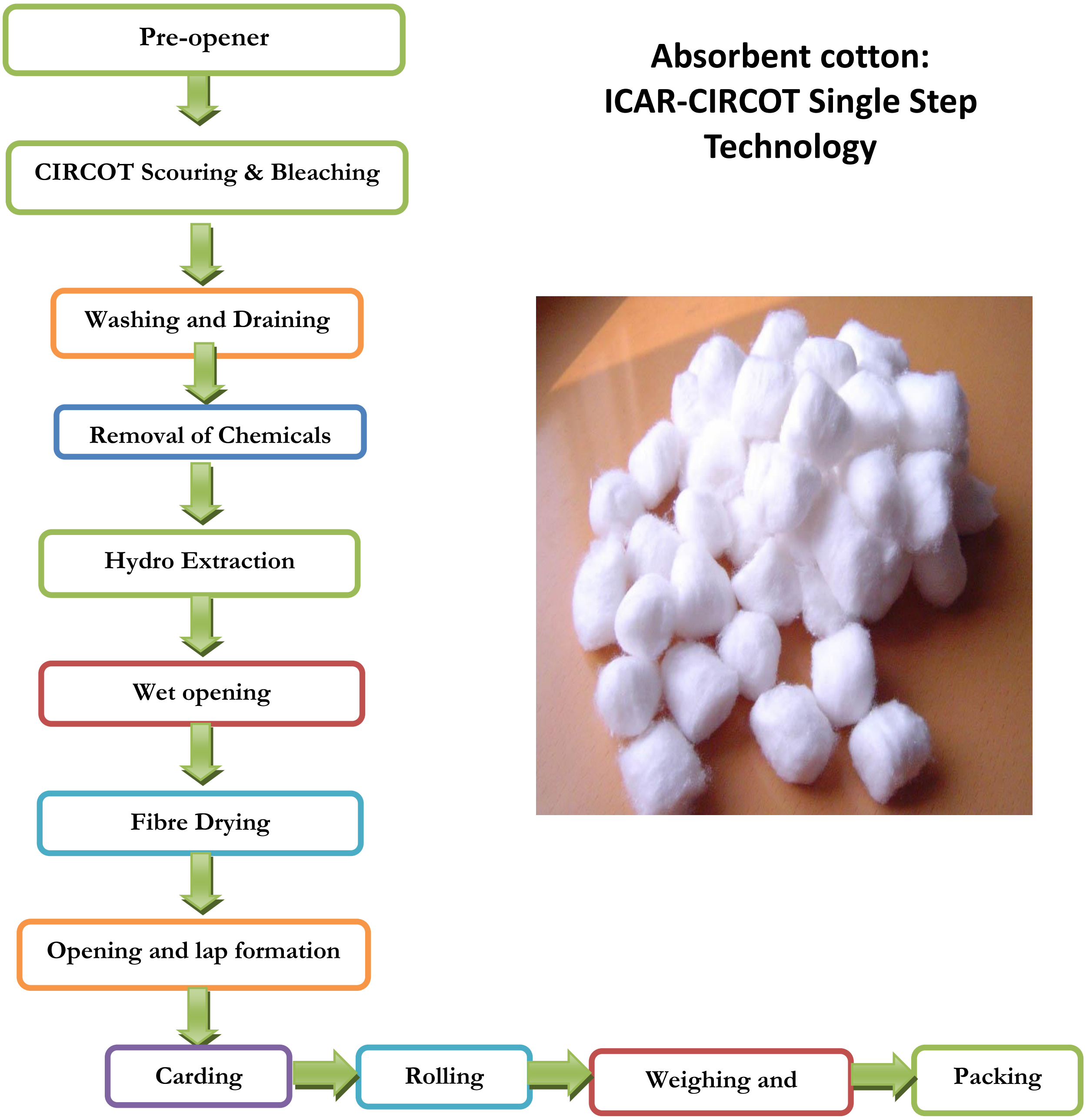
| | | | |
|---|---|---|---|
| Moisture Content | 7.5-8% | <8% | Hydroxyl groups in cellulose |

**Standard value required for absorbent cotton as per Indian Pharmacopoeia/I*

## Preparation of Absorbent cotton

For conversion of raw cotton into absorbent cotton that satisfies the standard norms, it should undergo both mechanical and chemical cleaning process. In the preparation of absorbent cotton for surgical purposes the main object is to obtain a product which is absolutely clean and highly absorbent. While usual methods of cotton scouring &bleaching are employed, certain precautions have to be observed in order to get highly purified product. It is essential that no substances be present that may cause irritation in a wound, and furthermore it is necessary that the cell wall of the cotton fiber be made as porous as possible. As a rule, stronger solutions of caustic soda are employed than when the cotton fiber is scoured for the purposes of yarn making because, the presence of small amount of wax will favor the spinning process. But for absorbent cotton all the waxes should be removed. The following sequence is followed for the processing of raw cotton.

## Absorbent cotton: ICAR-CIRCOT Single Step Technology




**Successful preparation depends on four factors:**

- The level and type of impurities present
- The quality and quantity of chemicals used in various stages of preparation.
- Good quality soft water without metallic ions.
- The type of machinery used for the scouring process.

**Scouring**

Kier is the name of the machine which is mostly used for the scouring of cotton materials. It is a high temperature pressurized vessel (HTHP) which can work up to 140°C. "Kiering" is the process which indicates the scouring process.

Conventionally, scouring is carried out and then the fiber is bleached. However single stage scouring and bleaching for the absorbent cotton preparation is possible by formulating effective recipe. Success of this process depends upon the level and type of impurities present in the material which is going to be kiered. For highly contaminated cotton, mostly it is advised to go for initial scouring followed by peroxide bleaching process. Besides the action of alkali in the scouring process, the effect of pressure in the kier is also to be considered. The degree of pressure and time of scouring process depends upon the size of the kier. The following points are to be considered for effective preparation of cotton to get highly cleaned absorbent cotton.

- The correct quantity of fiber in the kier
- Proper packing and loading of the kier
- The correct rate of liquor circulation
- Use of sufficient auxiliaries
- Optimum alkali and MLR
- The correct steam pressure and volume.
- Maintaining the kier in a clean condition
- Absence of air and oxygen in the kier
- Technical manpower

Normally less degradation of cotton fibre is taking place when it is boiled with alkali of optimum concentration up to 130°C in the absence of air. There would be 6-10% of weight loss after the scouring and bleaching process of cotton fibre.

**Bleaching**

Though whiteness of absorbent cotton is not an essential parameter as per Pharmacopeia Standard (IP), it is customary process to bleach the cotton fibres for absorbent cotton. Conventionally cotton fibres were bleached with hypochlorite solution after caustic scouring process. Permanency of whiteness is the major issue in the hypochlorite bleaching, also we can't combine scouring and bleaching using hypochlorite process. So peroxide bleaching is mostly preferred for the bleaching of cotton fibres. Optimum pH and stabilization of peroxide are the two very important parameters in peroxide bleaching. The time of the bleaching can be reduced by increasing the bleaching temperature. Normal working temperature for cotton fibres bleaching is 95°C 120°C. To increase the whiteness flourescent whitening agents (FBA) should not be used for the absorbent cotton.

For *sterile absorbent cotton* quality, no living microorganism should present in the final product. This can be achieved by gaseous sterilization of cleaned absorbent cotton. "Ethylene oxide” is the most commonly used gas for gas sterilization. It generally acts by the alkylation mechanism of several organic compounds of enzymes and finally making them inactive. "Sulfhydryl (-SH)" groups of enzymes are inactivated by ring opening and alkylation reactions of ethylene oxide. The effectiveness of ethylene oxide in the sterilization process depends on parameters like relative humidity, gas concentration, temperature, exposure time, and the extent of contamination. Normal working ranges for the ethylene oxide concentration and relative humidity are 500 - 1000 mg per litre and 30 - 60%, respectively.

**Patents Filed & Granted for ICAR-CIRCOT Absorbent Cotton Technology**

ICAR-CIRCOT, Mumbai has two granted patents for Technology for preparation of Absorbent Cotton

| Patent Application Number | Title of Innovation | Patent Grant Number |
|---|---|---|
| 1193/MUM/2001 | A New Single Stage Process for the Preparation of Absorbent Cotton from Short Staple Fibre Waste | 198339 |
| 366/MUM/2009 | A New Enzymatic process for the preparation of Absorbent cotton from non Spinnable Short Staple Cotton | 273512 |
| 368/MUM/2009 | A Biochemical process for Preparation of Absorbent Cotton from Non spinnable Cotton using Microbial Consortium | Date of Filing: 15.20.10 |

**Absorbent Cotton Demand**

The demand for Absorbent Cotton is directly proportional to population and expansion of public health services.

- **Largest consumer: Government hospitals and Large nursing homes**
- **Absorbent/Surgical Cotton Demand (Global)** is growing @ **10% per annum**
- **Absorbent/Surgical Cotton Demand (India): 2 million bales per year** (1 bale= 170 kg)
- Reason for steady growth rate of Absorbent Cotton in India
  - more people getting access to basic healthcare facilities,
  - affordable medical facilities as surgeries, transplants etc.,
  - increased awareness towards personal hygiene,
  - economic growth of towns and villages.

**Projected Demand of Absorbent Cotton**

According to a report by www.niir.org on surgical/absorbent cotton business published in 2017, till 2022, 3-3.5 million bales of cotton will be required to fulfill the domestic demand of absorbent cotton and more would be needed for the export market. Besides the Indian market, there is enormous export potential for surgical cotton in countries such as the US, EU and Japan, There is also a rise in demand for Indian surgical cotton in Middle East and African region.

| **Year** | **Quantity (Tonnes)** |
|---|---|
| 2013 | 323 |
| 2014 | 343 |
| 2015 | 363 |
| 2016 | 385 |
| 2017 | 408 |
| 2018 | 432 |
| 2019 | 459 |
| 2020 | 486 |
| 2021 | 515 |
| 2022 | 546 |
| 2023 | 579 |

## Conclusion

Demand for absorbent cotton is going to increase in future both due to increased domestic and international market demands. Medium and Short staple cotton fibers are economical and hence suitable for preparation of absorbent cotton. Successful processing of cotton fibers to get absorbency as per the required standard and quality depends upon the judicious choice of preparation method and good industrial practices.