Recent advances in fermentation technology for value-addition to cotton stalks and cottonseed

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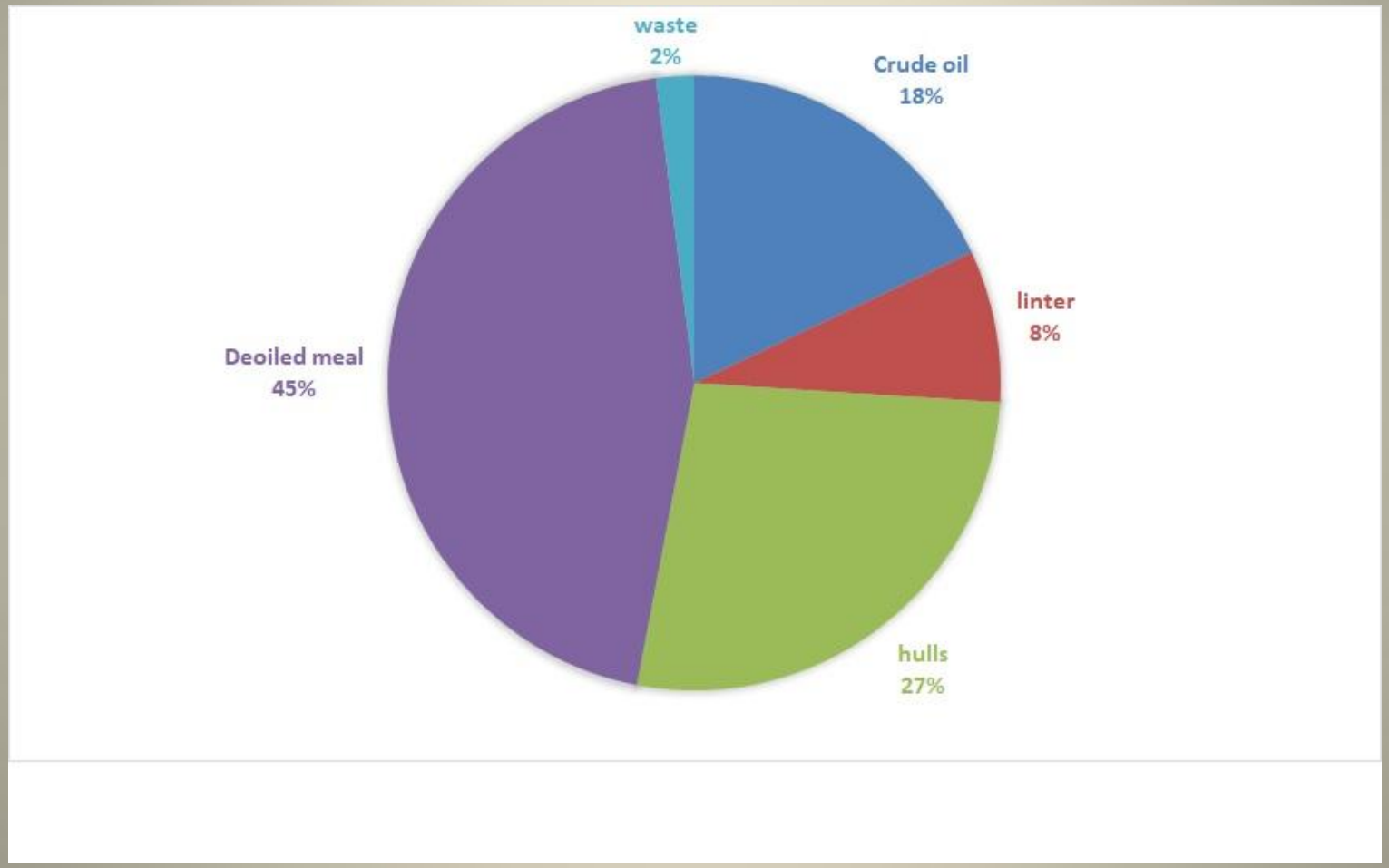
Introduction

- The two major by-products generated during cotton cultivation and processing are cotton stalks and cottonseed.
- In India, thirty and twelve million tonnes of cotton stalks and cottonseed respectively are generated annually.
- The value-addition of cotton by-products increases the value of cotton crop and thus brings additional revenue to the farmers.

Cottonseed

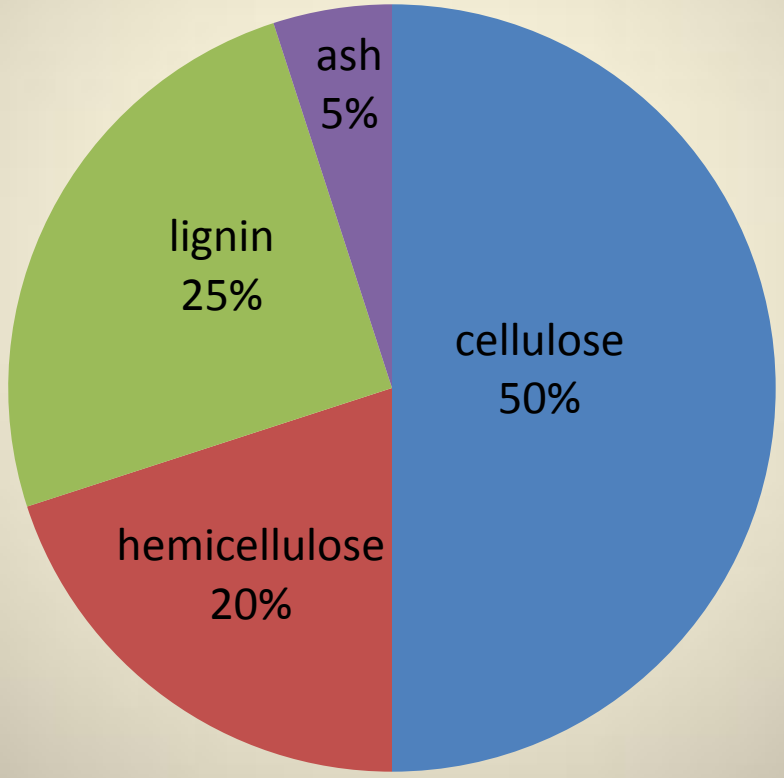
Cotton stalks

Scientific processing of cottonseed – theoretical yield



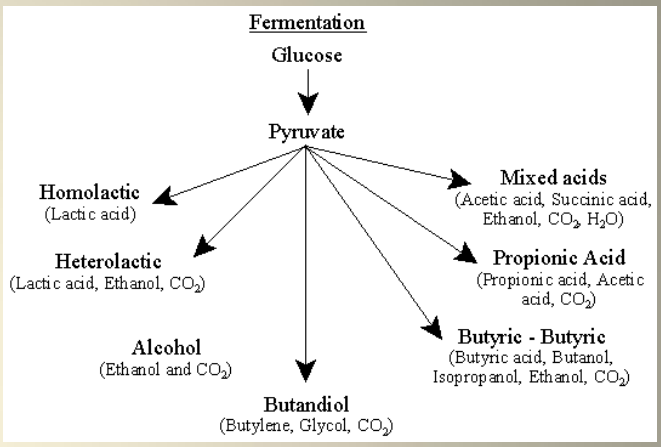
Cottonseed products from Scientific processing

Chemical composition of cotton stalks



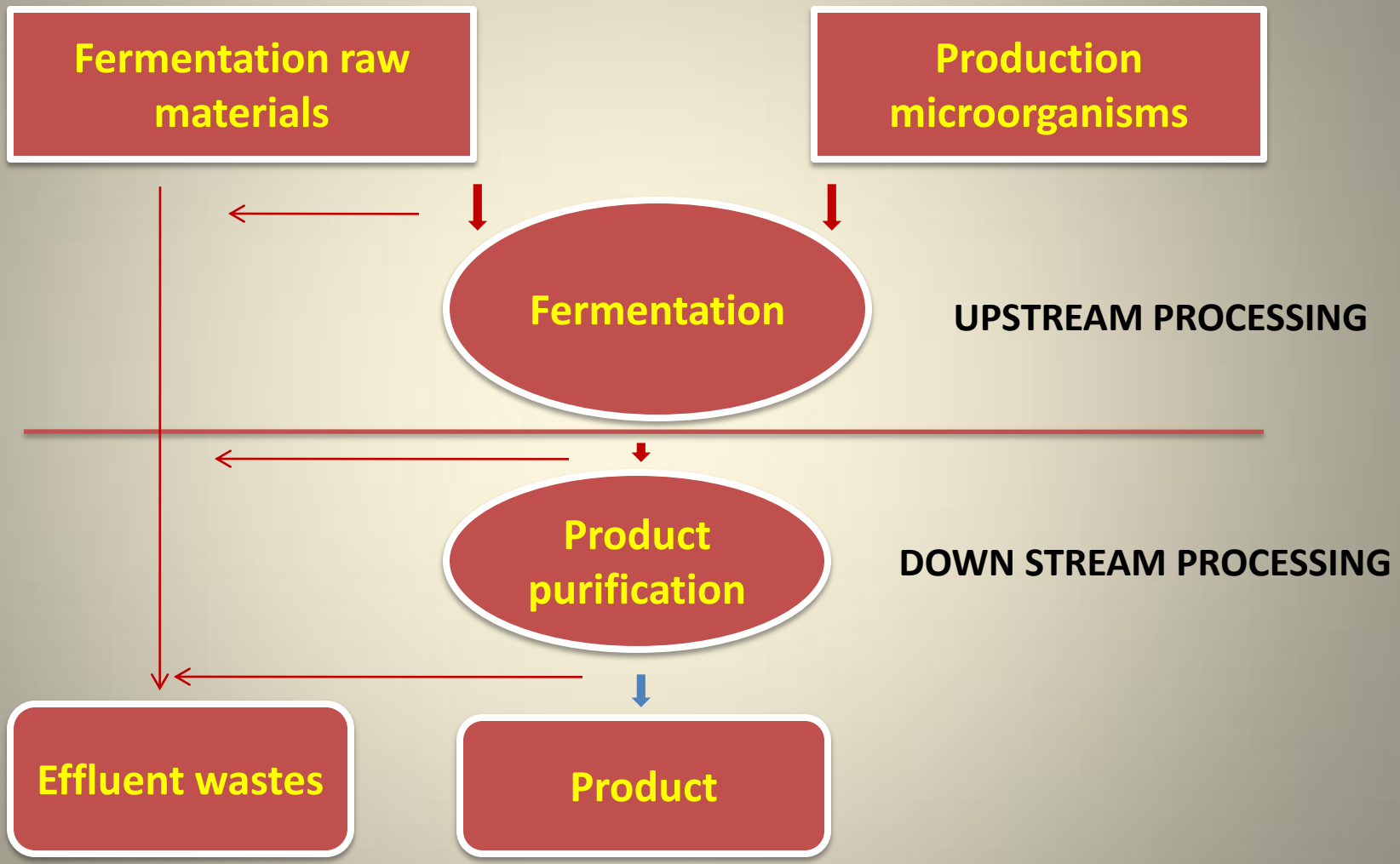
Fermentation

- Fermentation is the term derived from latin word “fervere” means “to boil” describing the action of yeast on fruits and malted grain. The anaerobic catabolism of sugars result in CO_2 production makes bubble like appearance (Stanbury et al., 1995).



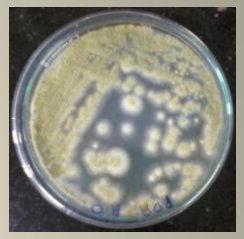
- The exploitation of microorganism’s for products and services for the well being of human kind popularly termed as “fermentation technology”.

An typical fermentation process (Waites et al., 2001)



Industrial microorganisms used in cotton by-products utilization

Microbial group	Species/strain	Applications
Filamentous fungi	*Pleurotus florida*, *P. ostreatus, P. sajor-caju, P. flabellatus, Phanerocheate chrysosporium, Aspergillus niger, A. fumigatus* and *A. oryzae*	Oyster mushroom cultivation in cotton stalks Bio-enriched compost production, Enzyme production
Yeast	*Saccharomyces cerevisiae, Candida tropicalis, C. lipolytica* and *Pichia sp.*	Animal feed, Single cell protein, Degossypolization in cotonseed cake/meal
Bacteria	*B. subtilis, B. stearothermophilus, Clostridium sp*.	Enzyme production, bio-scouring
Anaerobic consortium	Consortium of facultative anaerobes and anaerobic microbes	Enhanced oil and linter recovery, animal feed, biogas

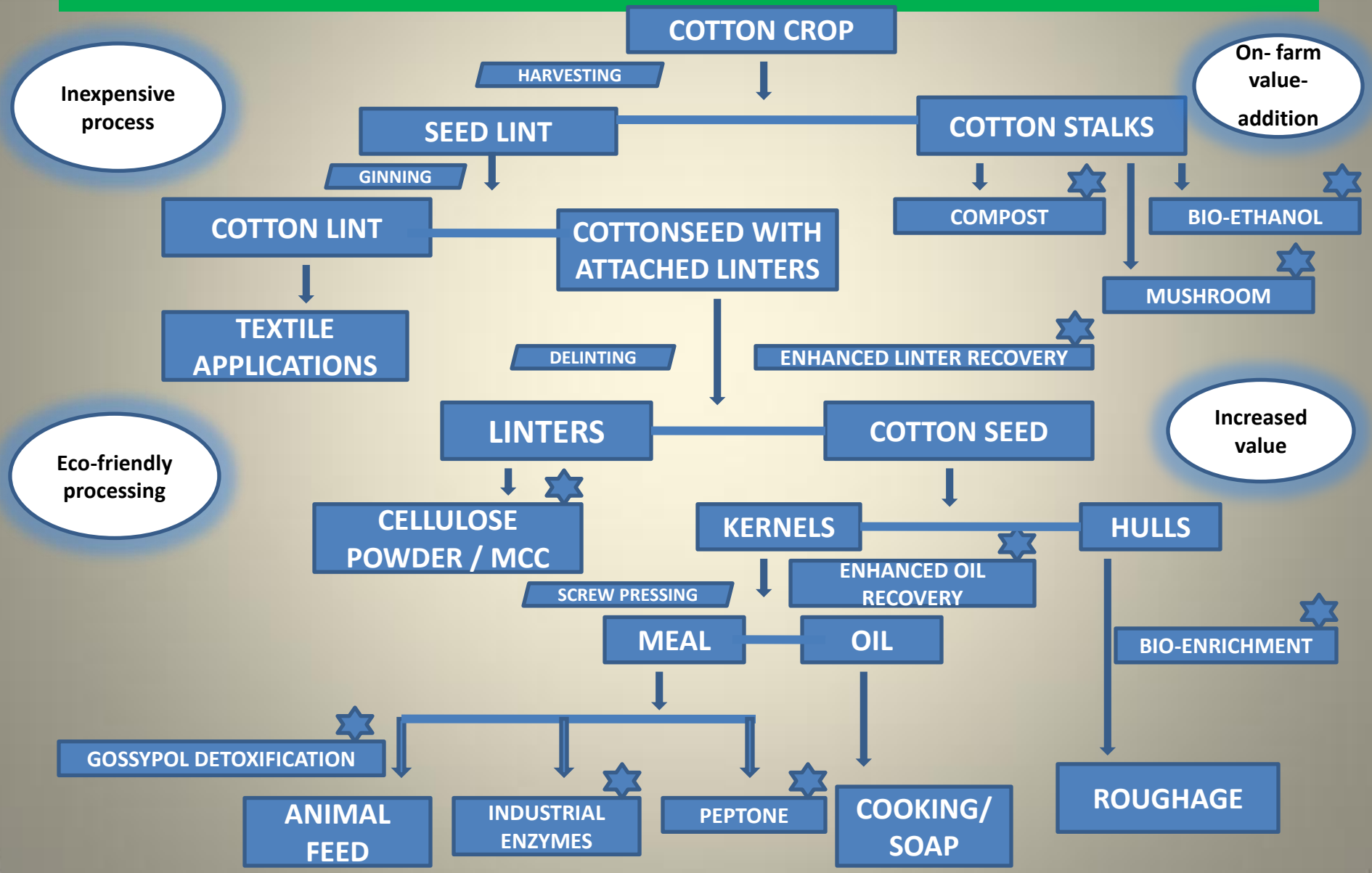


A. oryzae

S. cerevisiae

B. stearothermophilus

Interventions of ICAR- CIRCOT 's fermentation process for value-addition to cotton by-products



Enhanced linter recovery

At ICAR- CIRCOT, a microbial consortium was developed for the pretreatment with cottonseed for enhanced linter recovery (additional 1- 2%) during mechanical delinting process.

Apart from increased linter recovery the microbial treatment reduces the power consumption of delinting process.

Sample	Linter recovery (%)	Power consumed (units/tonne of seeds) (KPH)
Control	6.35	74
Treated	7.68	66

Cellulose powder from linters

- Cellulose Powder is widely used in pharmaceutical industry as an excipient, binder, dis-integrant and anti-adherent.

- Anaerobic method was employed for the preparation of pulp from crop residues including cotton linter which resulted significant reduction in release of toxic chemicals and conserved energy.

- The cellulase activity of CP prepared by anaerobic method was higher than the chemical process

Cellulose powder

Enhanced oil recovery

- **Cottonseed kernel was treated with ICAR- CIRCOT microbial consortium (1%) and incubated for half an hour. The treated cottonseed kernel was subjected for oil recovery using screw pressing method.**

- **The results showed 3% increase in oil yield in microbial consortium pre-treated cottonseed kernels**

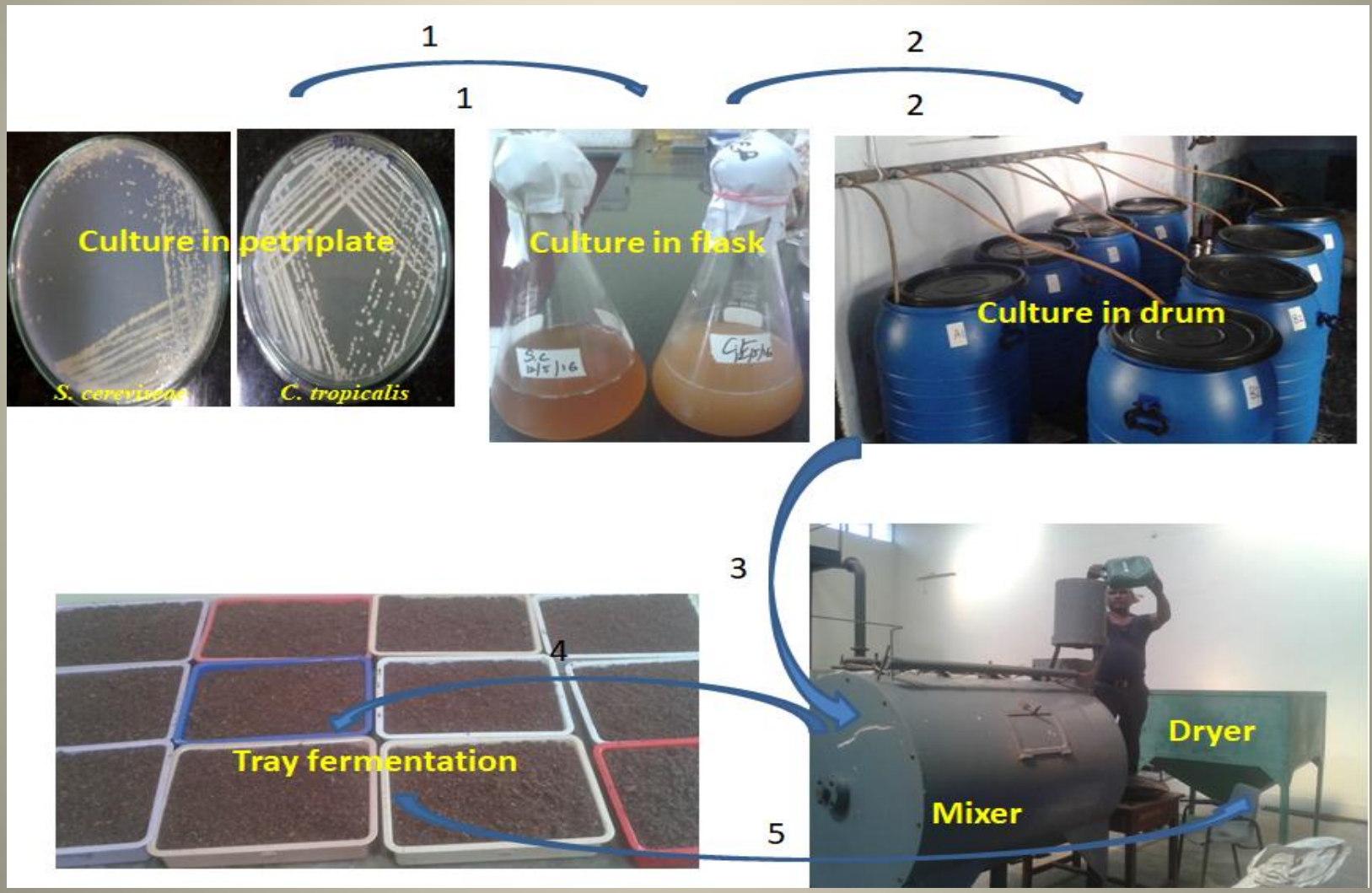
Treatment	Cottonseed kernel (weight in kg)	Oil weight (kg)	Oil cake weight (kg)	Percent oil recovery (screw press method)
Control	1000	200	765	20.0
Treated (microbial pretreatment)	1000	230	760	23.0

Degossypolization of cottonseed meal/cake

ICAR- CIRCOT has developed a solid state fermentation process in which, the reduction of free gossypol content (80%), bound gossypol (60 %), crude fibre (30%) and improvement of protein content (40%) and lysine content (25%) was achieved in cottonseed cake/meal.

Sample	FG (%)	FGR (%)	TG (%)	TGR (%)	Lysine (%)	Protein (%)	Crude fibre (%)
Treated	0.045	79.5	0.89	61.8	1.25	33.5	25.6
Control	0.22	-	2.32	-	1.00	20.1	37.1

Steps involved in microbial degossypolization technology



Peptone from cottonseed meal

- **ICAR-CIRCOT has developed a good quality peptone with desired degree of hydrolysis i.e. 28% when alkali (0.06%) pretreated cottonseed meal was hydrolysed with proteolytic enzymes namely pancreatin and papain in combination after about 18 h of incubation.**

- **The quality of cottonseed meal peptone was comparable with that of commercial product.**

Peptone	Total Nitrogen (%)	Amino Nitrogen (%)	Degree of Hydrolysis	Peptide Chain Length
Cottonseed Meal (ICAR-CIRCOT)	9.7	2.8	28.9	3.5
Cottonseed Meal(commercial)	8.7	2.9	33.3	3.0
Soybean Meal	11.7	3.5	29.7	3.3

Industrial enzymes from cottonseed meal peptone

The peptone from cottonseed meal induced the production of amylase and cellulase by *Penicillium funiculosum*

Enzyme (Filter paper assay) U/ml	Commercial product	CSM peptone
Cellulase	1320	1840
Amylase	20	81

Bio-enrichment of cottonseed hulls

ICAR-CIRCOT has developed an inexpensive anaerobic method for treatment with cottonseed hulls to improve the digestibility from 50 % to 60% and protein content from 4.6 to 7.5 respectively.

Economics of Scientific processing and Value-addition to cottonseed

A. Conventional whole seed crushing

Products	Rs. / tonne
Oil (12%)	6,600
Cake (80%)	17,600
Total	24200
Processing cost (-)	500
Cottonseed (-)	20000
Net profit	**3,700**

Price of the products (Rs. /kg)
Cottonseed – 20
Linters- 30
Meal – 25
Crude oil – 55
Hulls-15
Degossypolized meal – 30
Cottonseed cake-22
Bioenriched hulls - 20

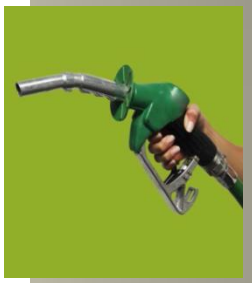
B. Scientific seed processing

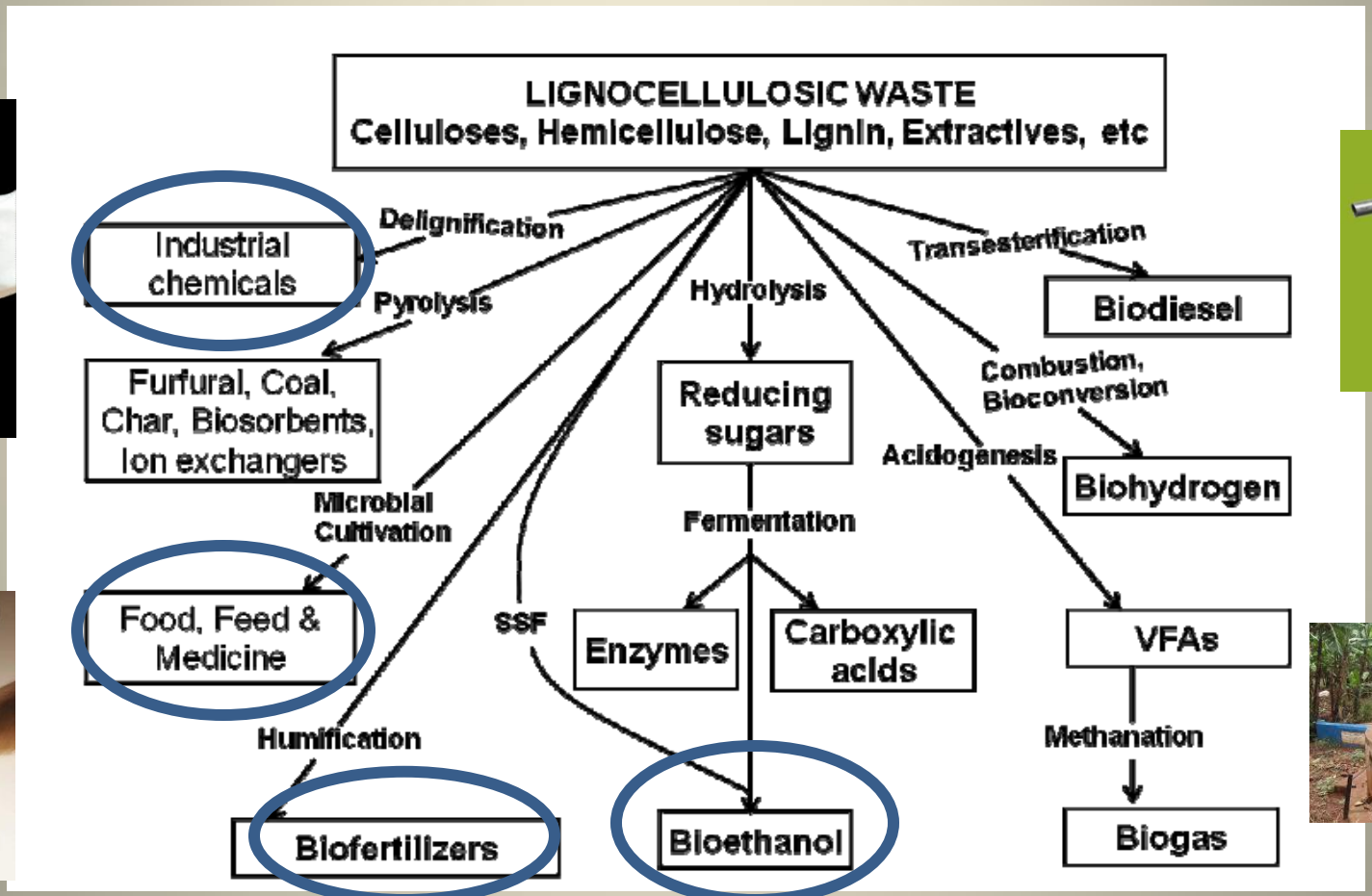
Products	Rs. / tonne
Linters(5 %)	1500
Hulls (35 %)	5250
Oil (16%)	8800
Meal (40%)	10,000
Total	25,550
Processing cost (-)	1000
Cottonseed (-)	20000
Net profit	**4,550**

C. Value-addition to cottonseed by-products

Products	Rs. / tonne
Enhanced Linters Recovery(7 %)	2100
Bio-enriched Hulls (35 %)	7000
Enhanced Oil Recovery (18%)	9900
Degossypolized meal (40%)	12,000
Total	31,000
Processing cost (-)	1500
Cottonseed (-)	20000
Net profit	**9350**

Bio-refinery approach of cotton stalks (a lignocellulosic biomass)





Value-added products from lignocellulosic- wastes (Mtui et al., 2009)

SSF = Simultaneous Saccharification and Fermentation; VFAs = Volatile Fatty Acids

Bio-enriched compost from cotton stalks

- An accelerated process for preparation of bio-enriched compost from wet and dry cotton stalks was developed.

- Wet cotton stalks – 45 days
- Dry cotton stalks – 60 days

- NPK content was three times higher than FYM

A- Cotton stalks B- Cotton stalks compost

S. No.	Physico-chemical parameters	Compost from wet cotton stalks	Compost from dry cotton stalks
1.	pH	7.1	7.3
2.	Organic Carbon (%)	22.2	30
3.	Total Nitrogen (%)	1.1	1.6
4.	Total Phosphorus (%)	0.9	0.8
5.	Total Potassium (%)	0.8	1.5

Oyster mushroom cultivation using cotton stalks

Common agro-residues used for oyster mushroom cultivation

- **Wheat straw**
- **Rice straw**
- **Saw Dust**

ICAR-CIRCOT developed a technology for cultivation of oyster mushroom in cotton stalks.

Cultivable species in cotton stalks

- ***Pleurotus florida***
- ***P. ostreatus***
- ***P. flabellatus***
- ***P. sajor-caju***

Oyster mushroom in trays

Crop duration : 30 days

Yield: Minimum 200 g per kg of dry cotton stalks

Hanging method for *P. florida* cultivation

Economic benefits of bio-enriched compost and oyster mushroom cultivation to the farmers

A. Economic benefit of bio-enriched compost preparation from cotton stalks

Parameter	Details
Yield of Compost	800 kg per tonne of cotton stalks
Production cost	Rs. 2960/- per tonne
Selling price	Rs. 3200/- per tonne
Benefit cost ratio	1.08
Cost savings over FYM	Rs. 9000/- per acre

A farmer can save a minimum of Rs. 9000/- per acre by preparation of bio-enriched compost from cotton stalks.

B. Economic benefit of oyster mushroom cultivation using cotton stalks

Parameter	Details
Yield of mushroom	200 g per kg of cotton stalks
Production cost	Rs. 50 per kg of fresh mushroom
Selling price	Rs. 80 per kg of fresh mushroom
Benefit cost ratio	1.6
Additional income	Rs. 10,000 per acre

A famer can earn additional income of Rs. 10,000/- by utilizing cotton stalks produced from an acre of land

At ICAR-CIRCOT, efforts were made to popularize these technologies among cotton growing farmers through awareness and demonstrations.

Industrial Chemicals: Cellulose and Lignin Powder

- Cotton stalks - a potential source commercial cellulose and lignin.

- Lignin - natural adhesive and could replace Phenol-Formaldehyde based synthetic adhesives in Plywood industries.

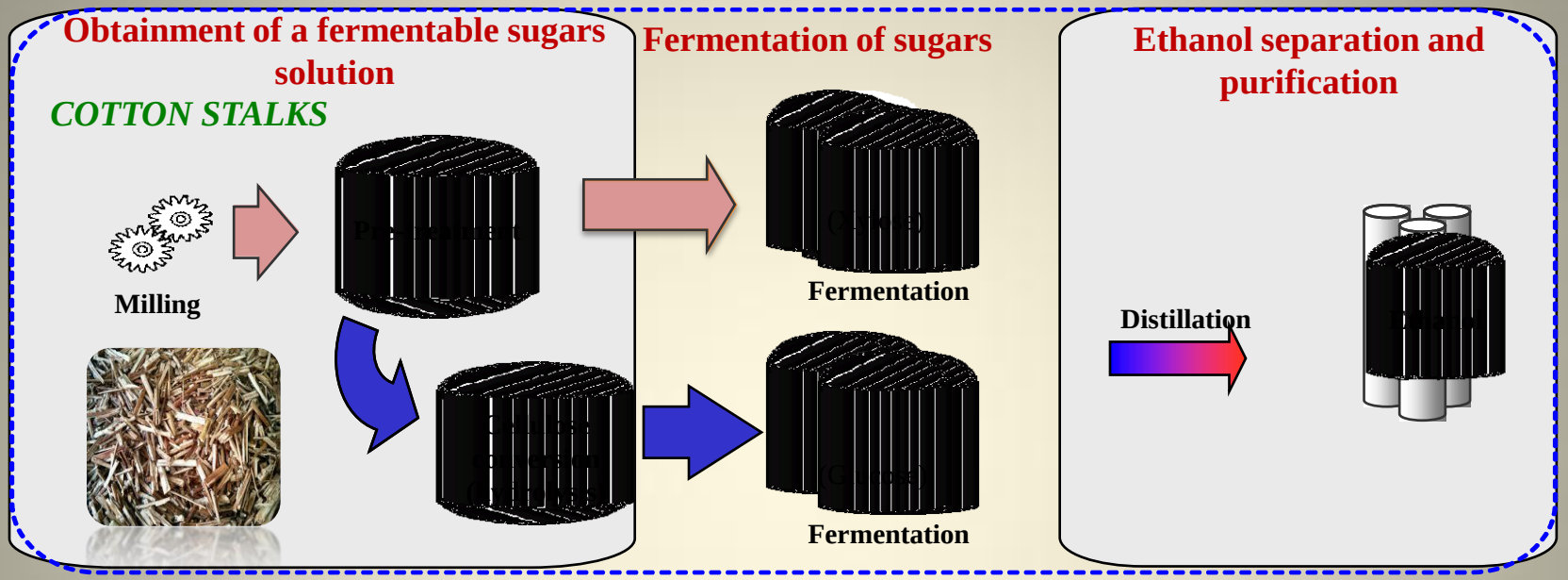
- Lignin Phenol-Formaldehyde (LPF) could substitute up to 50 % of phenol as wood adhesive

- Moreover, the derivatives of cellulose such as cellulose acetate, cellulose nitrate, carboxy methyl cellulose and lignin derivatives such as vanillin, quinones, benzene etc. have wider industrial applications.

Cellulose powder

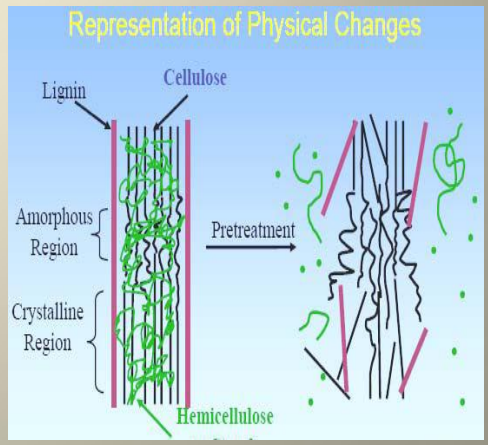
Lignin powder

Bioethanol from cotton stalks



The pre-treated cotton stalks had recorded higher recovery of reducing sugars and ethanol yield.

The reported ethanol yield from cotton stalks are 9.6 and 4.5 g/l (Baig et al., 2014 and Wang et al., 2016).



Pre-treatment of cotton stalks

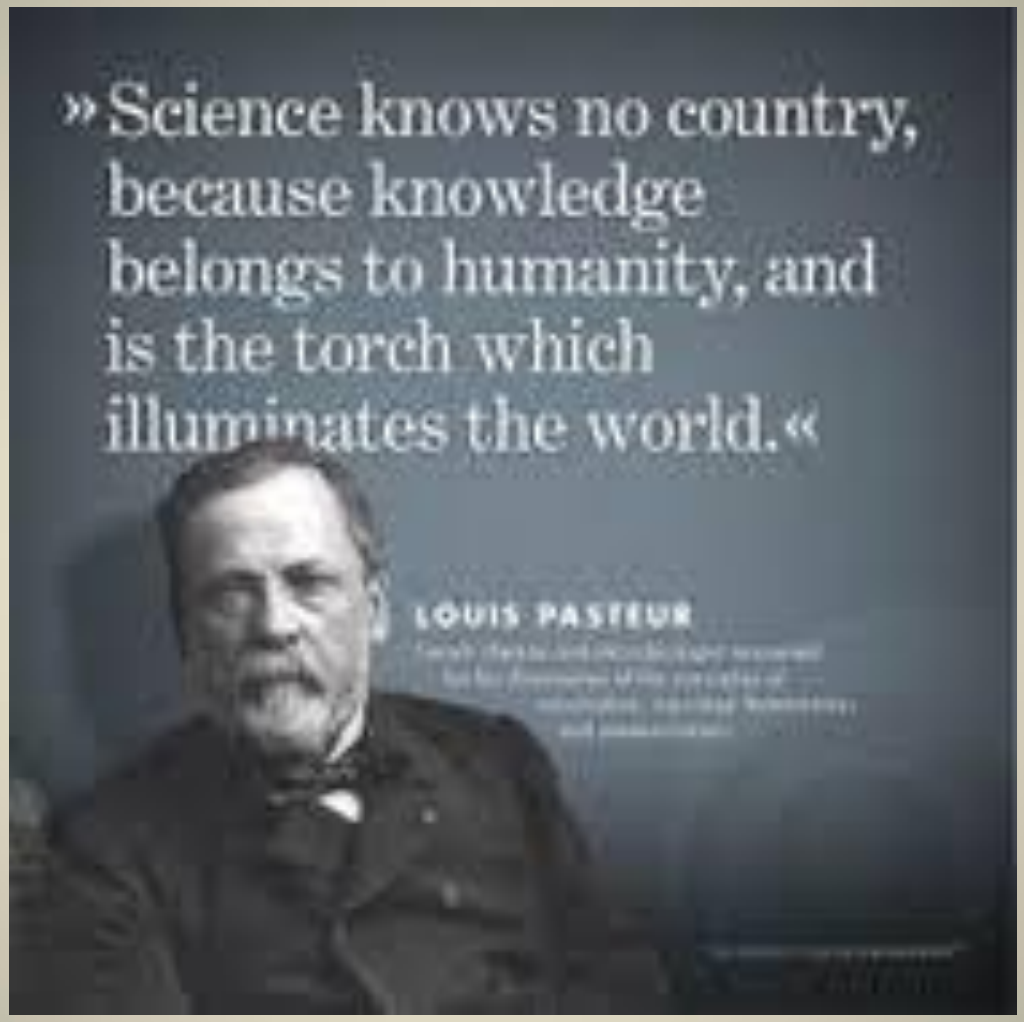
Conclusions

- **Fermentation technology has wide application in value-addition of cotton stalks and cottonseed.**

- **Value addition to cottonseed products makes scientific cottonseed processing more economically viable especially in small and medium level industries.**

- **The fermentative conversion of cotton stalks into valuable fuel, chemical and bio-manures leads to several benefits such as restoration of soil health, avoidance of burning cotton stalks in the field and enhancement of cotton productivity.**

- **Thus cotton growing farmers and cotton based industries would be benefitted.**


» Science knows no country, because knowledge belongs to humanity, and is the torch which illuminates the world.«
LOUIS PASTEUR


Thank you!