UTILISATION OF COTTONSEED BY-PRODUCTS

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Introduction

Cotton, the king of natural fibres is mainly cultivated for its lint which is the most sought after textile fibre till date due to its inherent ecofriendly and comfort characteristics. It is also one of the important cash crops of many of the Afro-Asian countries like India, Iran, Egypt, Sudan, Uzbekistan, Tanzania, etc. and plays a major role in their economic development. However, of late, cotton cultivation in general and especially in these countries is becoming non-remunerative on account of higher cost of inputs by way of plant protection measures, low productivity in rain fed cultivation, etc. As a result, the cultivators are not able to get adequate returns commensurate with their inputs. Hence, there is an urgent need to explore alternative means of increasing the returns from cotton farming. While efficient use of available resources, good quality seeds, organic cultivation, transgenic cotton etc. could reduce the cost of cultivation and enhance productivity, a judicious approach to promote the use of by-products from cotton cultivation through value addition route offers an attractive proposition to generate additional income to the farming community and the industries.

Cottonseed

It is well known that as much as 60-70% of seed is available from seed cotton during ginning. As per the estimate the production of cottonseeds in India during 2006-07 is 89.01 lakh tonnes as against 270 lakh bales (170 kg) of cotton. The cottonseed despite being rich in edible oil and protein, it has not received as much attention as it deserves. The seeds are stored in open and there could be chances of infection by fungi elaborating aflatoxins. Such seeds become unfit for feeding to cattle and even the meal cannot be exported. Efforts have to be made to utilize cottonseed more scientifically to realise good returns. The lint and seed yield in different species of cotton are given in Table 1.

Table 1: Lint and Seed Yield in Different Species

Species	Lint Yield	Seed Yield
G. arboreum	34	66
G.herbaceum	38	62
G.hirsutum	36	64
G.barbadense	29	71

The seeds obtained during ginning is considered as a by-product. The seeds when scientifically processed yield four individual components (Table 2).

Table 2: Cottonseed By-products

Linters	Short fibres still clinging to the seed after ginning
Hulls	A tough protective covering of the kernel
Oil	Extracted from kernel
Meal	Residue after extraction of oil

Utilisation of Cotton Linters

The linters are fuzzy short fibres which form a dense mat adhering to the surface of cotton seed. They are removed from seed surface by delinting machines. Based on delinting process adopted, linters are classified as first cut, second cut and mill run.G. hirsutum varieties have the highest linter content (about 10.5 %). Desi varieties have an average of about 4.3 % - 5.9 %. As much as 10,000 tonnes of linters in organised sector are available in our country each year. Linters are used for the manufacture of cellulose products like cellulose acetate, carboxy methly cellulose, viscose rayon, microcrystalline cellulose, cellulose nitrate, etc., preparation of specialty grade paper, absorbent cotton, etc. The data on the export of cotton linters is given in Table 3.

Table 3 : Export of Cotton Linters

Year*	Quantity (Tonnes)	Value (Lakh Rupees)
2005-2006	200000	140
2004-2005	77000	50
2003- 2004	170000	120
2002-2003*	Nil	-
2000-2001	8125	1283
1999-2000	2003	225
1998-1999	2291	243
1997-1998	7159	848
1996-1997	2131	323

* Export ban was invogue

Preparation of Pulp and Paper from Cotton Linters

The linter sample was mechanically cleaned using shirley trash separator. Cleaned linter samples were kiered with various concentrations of alkali (2%, 4% and 6%) in a rotary bomb digester at 160^0C for 2 h. The kiered samples were washed thoroughly and then converted into pulp by beating in a valley beater to desired freeness. Pulp samples were bleached in plastic containers using hypochlorite at 40^0C for 2 h. Standard paper sheets were prepared from all the pulps and evaluated for various strength properties. The test results indicated that the quality of paper was quite satisfactory. There was a gradual improvement in properties of paper with increase in the concentration of alkali from 2% to 6% while the yield levels showed a declining trend. The results are given in Table 4.

Table 4: Properties of Paper Prepared from Linters

Properties	2% NaOH	4% NaOH	6% NaOH
Grammage	60 ± 1	60 ± 1	60 ± 1
Burst Factor	19	24	29
Tear Factor	107	128	143
Breaking length (m)	2997	3216	3849
Number of Double Folds	38	46	78

High Grade Pulp from Cotton Linters

High grade pulp from cotton linters was prepared by digesting mechanically cleaned cotton linters in rotary digester with 7.5 % NaOH at 165^0C for a period of 3.5 h. (which included about 1.5 h to reach the maximum temperature). The material to liquor ratio was 1:6. The cooked material was washed thoroughly and then bleached using sodium chlorite. The bleached pulp was washed thoroughly and then air dried. The pulp was characterised by carrying out standard test methods. The profitability of high grade pulp from linters is given below.

Costing of pulp from linters (per tonne)

	Rs.
Raw material @ Rs.20/kg)	20,000.00
Chemical (NaOH)	240.00
Water	105.00
Bleaching chemical (Hypo) and peroxide	600.00
Electricity and Labour	1200.00
Overheads	1200.00
Expected yield of pulp (80%)	800 kg
Expected sale price (@ Rs.50/kg)	40,000
Running cost	23,345
Depreciation @ 10%	340
Net profit (per day) during value addition	16,315
Total profit per day	36,315

Uses of High Grade Pulp from Linters

The high grade pulp is a good raw material for preparing viscose grade fibres, cellulose acetate, cellulose nitrate, specialty grade paper and microcrystalline cellulose.

Cotton Linter-dust

During cleaning of cotton linters, about 20% of dust is generated which contains high percentage of lignin (from seed coat fragments) apart from cellulose, pectins and ash. It has been found out that this material can be fed directly into cow-dung based biogas plants to obtain better methane production. Even batch digestion of this material, it is possible to produce about 600 litres of biogas in 45 days retention time per kg of material. The methane percentage would be around 60%.

Cottonseed Hulls

Bioenriched Cattle Feed

Cottonseed hull is a conventional feed for cattle and is a by-product of seed crushing industry. Cottonseed hulls are available in abundance and are rich in cellulose content but poor in digestibility. The presence of lignocellulosic bonds makes the material difficult to digest by ruminants. It is well known that microorganisms attack lignocellulosic bonds of these materials resulting in improved digestibility of the materials. The digestibility of cottonseed hulls could be improved by subjecting to an inexpensive anaerobic treatment with mixed microbial consortium for 7 days at room temperature.

The anaerobically treated cottonseed hulls were analysed for various chemical constituents. The result given in Table 5 indicates that the percentage of crude protein has increased to 7.5 from an initial value of 4.6. The digestibility percentage (IVRD) has increased to 60% from an initial value of 50% (Table 5). Feeding trials were undertaken on crossbred lactating cows at NDRI, Karnal to ascertain the efficacy of the treatment.

Table 5: Chemical Constituents of Cottonseed Hulls

Chemical Constituents (%)	Cottonseed hulls	
	Untreated	Treated
Dry matter	89.2	90.3
Nitrogen	0.7	1.2
Protein	4.6	7.5
Crude fibre	57.6	53.2
Ash	2.2	3.0
Ether extractives	1.8	1.1
Holo Cellulose	62.1	56.5
Cellulose α	40.4	35.5
Cellulose β	12.1	13.4
Cellulose γ	9.6	7.6
Reducing sugar	0.3	0.1
Total sugar	1.9	2.2
Digestibility	50.0	60.0
NDF	96.3	91.6
ADF	75.1	73.4
Lignin	20.9	23.4
Acid insoluble ash	1.2	1.4
NFE	23.0	25.5

NDF: Neutral Detergent Fibre ADF: Acid Detergent Fibre NFE : Nitrogen Free Extractives

Animals preferred the fermented products over untreated ones as indicated by the total voluntary intake in lactating crossbred cattle under different dietary treatments.

Digestible nutrient intake and their digestibility coefficients showed a significant difference between control and treated groups.

There was no significant increase in the milk yield in the case of cottonseed hulls. However, animals were healthy indicating that cottonseed hulls nutritive value is on par with other conventional roughages despite a slightly higher feed intake in the case of treated hulls.

Non-conventional lignocellulosic materials can be made to useful fermented products by appropriate pretreatments. They can definitely serve as fillers in a blend rather than wholesome feed. They can definitely act as acid absorbers in the rumen system and helps in slow release during metabolism. The load on alkaline saliva production to neutralise the acids produced during lignocellulose digestion will be reduced.

Scale-up trials are possible to enrich lignocellulosic materials in clusters around dairy farms by installing specific size digesters to supply fermented products without drying. This helps in better intake and digestibility, as it is well known that drying impairs both. Nitrogen loss will be prevented by feeding fermented products directly.

There is less loss of total organic matter (5% to 10%) during anaerobic treatment and hence a better treatment over the methods known so far where the loss has been upto 40%.

The method adopted being solid state fermentation, there is no generation of any effluents and the enriched material can be directly fed to cattle by mixing with concentrates.

Cottonseed Cake

Presently, in India, whole seeds are crushed and oil is extracted in which case the oil recovery is only 11-12%. The cake thus obtained is fed to cattle. The crude protein in the cake is about 25-27%. When kernels are used for extraction of oil, the recovery of oil is much better and cake fetches a better price due to high protein and good colour. Yellowish green colour is preferred. The protein in this cake is about 40%.

Cottonseed Meal

Cottonseed meal is a product of oil extraction. Solvent extracted meal has about 50 % protein. A method has been standardised to prepare peptone (Protein hydrolysates) from cotton seed meal, which has various microbiological applications. Cottonseed meal is a good source of protein. Hydrolysis conditions for preparation of protein hydrolysate from cottonseed meal by two proteolytic enzymes, pancreatin and papain were standardised. It was observed that good quality peptone with desired

degree of hydrolysis i.e. 28% was achieved when alkali (0.06%) pretreated cottonseed meal was hydrolysed with proteolytic enzymes namely pancreatin and papain in combination. The results are given in Table 6. The quality of the product was found to be better after 18 h incubation.

Table 6 :Characteristic of Peptone at Different Stages of Hydrolysis

NaOH Pretreatment (%)	Enzymes	Time of incubation (h)	Total Nitrogen (%)	Amino Nitrogen (%)	Degree of hydrolysis (%)	Peptide Chain Length
0.06	Pancreatin + papain	18	09.7	2.8	28.9	3.5
0.06	Pancreatin + Papain	24	11.3	2.9	25.7	3.9

The peptone was found to induce cellulase and amylase significantly as compared to the commercial product when Penicillium funiculosum and Bacillus subtilis were grown in the respective media. The results are given in Table 7.

Table 7:Production of Enzymes on Cottonseed Meal (CSM) Peptones

	Commercial Product	CSM Peptone
Cellulase (Filter Paper Activity	1320	1840
Amylase	20	81

One tonne of cottonseed when directly sold will fetch about Rs. 10,000/tonne. When whole seeds are crushed for oil, about 12% maximum oil recovery is possible.

Table 8:Whole Cottonseed Crushing

	Rs./tonne
Whole seed	10,000
Oil (12%)	5,640
Cake (80%)	8,000
Total	13,640
Cost of Production	400
Net Profit	3,240

Table 8 shows that it is possible to realize a net profit of Rs. 3,240/- per tonne. But about 8% oil is lost since it remains in the cake i.e. about Rs. 3,760 per tonne is lost. The high percentage of oil in the cake when fed to cattle is not going to be used by the animals and hence this has to be discouraged.

The same material when scientifically processed yields four useful by-products which can fetch a net profit of about Rs. 5250/- i.e. an additional gain of

Rs. 5,475/- from same one tonne material. Further, the by-products obtained will serve as raw materials for other industries Table 9.

Table 9:Prices of Cottonseed By-Products

	(Rs./Tonne)
Whole Seed	10,000
Linters (5% recovery)	1,000
Hulls(35% recovery)	1,750
Oil* (20% recovery)	9,500
Meal (40% recovery)	4,000
Total	16,250
Cost of Production	1,000
Net Profit	15,250

*from kernels
Price: Seed –Rs.10/kg, Linters-Rs.16/kg, Hull-Rs.5/kg, Meal-Rs10/kg, Oil-Rs47/kg

Table 10: Value Addition to Cottonseed By-products

Value Added products	Per tonne of seeds (kg)	Price (Rs.)	Cost of Production (Rs.)	Net Profit (Rs.)
Bleached Linters (70% yield)	35	2275	100	2175
Bioenriched Hulls (80% yield)	280	2040	350	1690
Oil	200	9400	-	9400
Meal*	330	8250	1000	7250
Oil from meal (7%)	70	3240	-	3240
			Total	23,755

*Preparation of protein hydrolysate from meal (60% recovery) will fetch a further profit of Rs. 62049/- (Rs. 59,400 + Rs. 2,640)

Price: Bleached Linter-Rs.65/kg, Solvent extracted meal-Rs.25/kg, Protein hydrolysate- Rs.800/kg

The value addition to by-products is given in Table 10. One can realize a total amount of Rs. 23,755/- as against an amount of Rs. 15,250/- when sold as it is. In other words a net gain of Rs. 8,505/- could be realized on value addition to the by-products.

Cottonseed Oil

The production of cottonseed oil during 2006-07 was 9.89 lakh tonnes as against 8.14 during 2005-06. The cottonseed contains about 18-25% oil depending on the quality of seed and the species. The oil is primarily used as a medium for frying and for manufacture of hydrogenated vegetable products, cooking, salad dressings and for production of soap. This is one of the important edible oils and is much superior in

its nutritional value to many of the traditional oils. As per an estimate, about 90 lakh tonnes of cottonseeds produced in India can yield approximately 15 lakh tonnes of oil. The nutritional value of cottonseed oil is around 9 kcal/g, the average digestibility is around 97% and could be compared with that of soybean, safflower and sunflower. The oil with practically no gossypol is pale yellow in colour and rich in Vitamin-E and can be used directly as a cooking medium and also for the manufacture of Vanaspati. The keeping quality of oil is also quite good and is comparable with other edible oils.

Utilisation of cottonseed oil for human consumption should receive immediate attention in our country for meeting the shortage of edible oils. It contains more than 50% of poly - unsaturated fatty acids and is very ideal in human diets. This oil is very popular in USA. However in India, it is being used to a very small extent. Therefore efforts are to be made on a war footing to popularise its use in our country which can result in stoppage of import of other edible oils, atleast to some extent. Efforts are also needed to popularise cultivation of varieties of cotton with high percentage of oil (25%).

Why the cottonseed oil is highly acceptable as an edible oil?

Even though cottonseed oil is darker in colour than soybean, peanut and other traditional oils, the impurities and pigments are readily removed by modern refining and bleaching techniques to produce light colour.

It possesses properties that makes it suitable for processing in salad oil. The proportion of highly saturated glycerides is such that when the oil is chilled slowly the higher melting glycerides separate out and can be readily removed by filtration which do not get crystallised when held at40° to 45° F. The high melting portion is generally utilised in blended oils for shortening or in hydrogenated products.

It contains traces of fatty acids with unsaturation greater than linoleic acid. On hydrogenation, the unsaturation decreases and stability is further increased. Unlike soybean oil, this oil has greater resistance to flavour reversion. The stability is also due to the presence of antioxidants namely tocopherols.

Refined Cottonseed Oil

It is one of the few oils which is in "OK FOOD" list of American Heart Association (AHA). The oil is nutritive as is certified by AHA. It is safe and suitable for human consumption. It contains 50% linoleic acid which is required in human diet as it is not biosynthesised in our body. The fatty acids are essential for synthesis of various hormones without which the internal vital organs of our body cannot function properly.

Another advantage is that it does not allow speedy blockening of coronary arteries by forming hard pellets of cholesterol. In view of the above, cottonseed oil should be made mandatory to be used in the form of blend either with oil or with hydrogenated vanaspati. It can also be supplied in the form of encapsulated materials. The fatty acid profile is given in Table 11.

Table 11: Fatty Acid Composition of Various Edible Oils

Oil Source	Fatty Acids (%)						
	Myristic (14:0)	Palmitic (16:0)	Stearic (18:0)	Others	Oleic (18:1)	Linoleic (18:2)	Linolenic (18:3)
Cottonseed	0.79	24.70	2.20	-	20.87	50.76	-
Groundnut	-	13.69	1.96	3.28*	52.13	28.94	-
Sunflower	0.38	4.27	5.46	-	49.41	40.48	-
Safflower	1.50	3.00	1.00	-	33.50	61.00	-
Til	-	10.02	5.85	-	40.11	44.02	-
Soybean	-	10.33	3.86	-	26.52	52.92	6.37
Corn	-	14.98	1.31	-	34.12	49.59	-
Mustard	-	2.10	0.39	3.01*	10.31	13.80	11.52
Coconut	18.76	8.38	2.18	62.17*	6.96	1.55	-
Palm	1.50	45.00	4.00	-	39.00	10.50	-

* This includes caproic, caprylic, capric, lauric, arachidic, dehenic and lignoceric either all or few in different properties

Palmitoleic (16:1), Cottonseed 0.68%, Mustard 0.26%
Elcosenoic (20:1), Mustard 7.39%
Decosenoic (22:1), Mustard 51.2%

Conclusion

Cotton plant despite being grown mainly for lint, 60% of seed obtained during ginning is an important by-product. It is possible to realize better profit by scientifically crushing cottonseed and selling the by-products namely, linters, hulls, meal and oil. On adding value to these by-product, the price realization is much better. In other words whole seed crushing gives a benefit of Rs. 3240/- per tonne, scientific crushing Rs.15,250/- per tonne value addition to by-products, Rs.23,755 or Rs.54,890/- if the solvent extracted meal is converted to protein hydrolysates. The high cost of cotton cultivation appearing non-remunerative considering only the price of lint, the proposition of considering the crop as a composite one is highly rewarding. The farming community to be educated through rigorous awareness programmes to gin the cotton at a small group level in the village and sell lint and seed separately, to reap a good harvest. In the existing system, farmers are deprived of their share due to the predominance of other agencies operating the system of procurement and sale of seed cotton.

REFERENCES

1. Balasubramanya, R.H. and Bhatawdekar, S. P., Biological Method of Improving the Digestibility of Cattle Feed, Indian Patent pending, filed in 2004.
2. Bhatawdekar, S. P. and Balasubramanya, R.H., Process for the Preparation of Peptone from Cottonseed Meal by Enzymatic Hydrolysis, Indian Patent No. 19270/BOM/1997.