Beyond the Fibre

Capturing cotton's full value in Africa

International Trade Centre

TRADE IMPACT FOR GOOD

The International Trade Centre (ITC) is the joint agency of the World Trade Organization and the United Nations.

Street address: ITC
54-56, rue de Montbrillant
1202 Geneva, Switzerland

Postal address: ITC
Palais des Nations
1211 Geneva 10, Switzerland

Telephone: +41 22 730 0111

E-mail: itcreg@intracen.org

Internet: www.intracen.org/publications

Beyond the Fibre

Capturing cotton’s full value in Africa

About the paper

Cotton by-products – such as cottonseed oil and oilcakes – can contribute meaningfully to reducing poverty, creating jobs and increasing economic growth in Africa. These derivatives can represent up to 30% of the value of seed cotton. Yet oil and cakes have not been fully exploited, despite a potential of 400,000 tons of oil and 500,000 tons of protein – vital for the growing livestock industry. Stalks and other by-products have also been neglected.

This paper explores ways of capturing the full value of cotton in Africa. It illustrates the benefits of a more systematic way of exploiting the substantial untapped potential of cotton by-products.

Publisher: International Trade Centre

Title: Beyond the Fibre: Capturing cotton's full value in Africa

Publication date and place: Geneva, December 2020

Page count: 54

Language: English

ITC Document Number: SEC-20-56.E

Citation International Trade Center (2020). *Beyond the Fibre: Capturing cotton's full value in Africa.* ITC, Geneva.

For more information, contact: Matthias Knappe, knappe@intracen.org

Foreword

Cotton is a strategic crop for many African economies, generating income and employment for millions of rural families, as well as export revenues for producing countries. Cotton is grown mainly for its fibre, the raw material to manufacture textiles and apparel.

Faced with low margins, high volatility in seed cotton prices and weather risks, farmers switch to and from cotton, depending on the previous season's price relative to other crops.

To grow cotton sustainably, farmers need year-round, income-generating opportunities. For example, they can use cotton fibre for hand-spun yarn, weaving it into fabrics they can use themselves, and also sell in domestic, regional and international markets. They can also add value to products stemming from the plant and the seeds, referred to as cotton by-products.

However, cotton stakeholders in Africa – from farmers to ginners to regulatory bodies – lack vital information on ways to add value to parts of the cotton plant other than the fibre.

This publication provides an overview of uses for cotton by-products in Africa. It offers recommendations for cotton stakeholders, starting with farmers, to benefit from more systematic use of cotton by-products.

For example cotton plant biomass (mainly stalks) can be used instead of firewood, reducing deforestation. Cottonseed oil, oilcakes and meals have many uses.

In many African countries, the price farmers receive for their product, called seedcotton, is based on the fibre's value. With an increased value of the seeds, farmers could capture this value for an overall higher price.

There are activities that can raise value, boost awareness among private and public stakeholders, and increase transparency in the cotton sector. Financial and technical assistance from funders and partners is needed to promote this value addition. Support for businesses that process by-products is essential, along with building capacity to set up industry clusters and encourage South-South cooperation.

This report forms part of the International Trade Centre's contribution to the cotton by-product value addition in partnership with the WTO and UNCTAD. The initiative is a direct response to a request from the Cotton Four – Benin, Burkina Faso, Chad and Mali – and other African countries. The paper also underscores the International Trade Centre's close engagement with the Cotton Four and its goals to develop cotton in Africa.

Pamela Coke-Hamilton
Executive Director
International Trade Centre

Acknowledgements

ITC commissioned this report as part of its joint initiative with the World Trade Organization and the United Nations Conference on Trade and Development to support the development of cotton by-products in Africa.

Gérald Estur, International Consultant, wrote this publication under the supervision of Matthias Knappe, Senior Officer and Programme Manager, Fibres, Textiles and Clothing (ITC).

We are grateful to the industry stakeholders, South-South cooperation partners in India and Turkey, and farmers and entrepreneurs in Africa and India who shared their experiences and lessons learned.

Special thanks go to Keshav Kranthi, Head of the Technical Information Section at the International Cotton Advisory Committee; Kris Terauds, Economist at the United Nations Conference on Trade and Development, for involving ITC in some activities related to its Promoting Cotton By-products in Eastern and Southern Africa project; and P.G. Patel, Director of the Central Institute for Research on Cotton Technology in India, with whom ITC has a long-standing collaboration on cotton development in Africa.

Jayna Kika, Senior Programme Assistant for Fibres, Textiles and Clothing (ITC), and Mariana Tavares, International Consultant (ITC), reviewed the paper in its final stages.

We would also like to thank Natalie Domeisen and Anne Griffin (both ITC), who oversaw the editing and production process; Jennifer Freedman, who edited the report; and Franco Iacovino (ITC), who provided graphic and printing support.

Contents

Figures, Tables, Boxes

Acronyms

Unless otherwise specified, all references to dollars ($) are to United States dollars, and all references to tons are to metric tons. Percentages in some graphics may not total 100% due to rounding.

ICAC	International Cotton Advisory Committee
ITC	International Trade Centre
USDA	United States Department of Agriculture

Executive summary

About 35% of the cotton lint produced across the world is traded internationally. Yet the global market for cotton by-products is very thin, as these goods are typically consumed where they are produced. This is also one reason that no recognized benchmarks for international prices of cotton by-products exist.

Nevertheless, the market for cotton by-products is growing in Africa and they could be an important complementary source of revenue for the cotton sector.

Despite their potential, cotton by-products have received little attention in sub-Saharan Africa. This potential has yet to be maximized, and African markets for by-products such as cottonseed oil and oilcake are not well developed.

The status of cotton by-products is similar across all producing countries in sub-Saharan Africa, as they share common characteristics and face the same constraints and challenges. Cottonseeds, oil, cake and meal are used to some extent, while linters and ginning waste are rarely used. Fewer than 10% of African cottonseeds are treated for use as planting seeds. Most oilseeds that are produced are sold to oil crushers.

This means the full potential of cottonseeds as an additional source of income to reduce poverty and fight climate change has not been exploited. There is potential in Africa to further commercialize cotton by-products in the following areas:

- Cottonseed oil, which competes with other vegetable oils, is typically used for human consumption (sometimes for soap manufacturing and other industrial uses such as plastics and pharmaceuticals);
- Cottonseed hulls are used either to generate energy for the processing facility or are blended with meal for animal feed and, less often, as fertilizer;
- Cottonseed cake, which competes with other meals, is used as animal feed;
- Linters are a source of cellulose used in goods such as yarn, plastics and filling material;
- Unprocessed cottonseed is sometimes used for animal feed;
- Cotton stalks can be used for compost, boiler fuel (briquettes, pellets) or particle boards, or to prepare pulp and craft paper.
- Edible mushrooms can be grown on cotton stalks.

Most cotton-producing countries in Africa have industries that process cottonseed into edible oil and livestock feed. Still, technologies to add value to other cotton by-products are underused on the continent due to a lack of information about modern and adapted tools available in other countries, insufficient data to assess the viability of investments in these products and inadequate policies to support the development of cotton by-product industries. Therefore, there is considerable scope to add value to such cotton by-products.

In recent years, the value of cotton by-products has increased faster than the value of lint. This trend is likely to continue as demand for edible oil and livestock and poultry feeds is growing in Africa, exceeding domestic production. This means cotton by-products may be able to compete with lint as income sources for many stakeholders and contribute significantly to the profitability of the cotton subsector as well as to income generation, employment and poverty reduction.

This paper offers several recommendations on how to capture additional value from cotton by-products. They include:

- Identify and assess value addition activities (processing and marketing of cotton by-products) in the national context;
- Raise awareness among private and public stakeholders (farmers, ginners, crushers, government officials) on the potential of cotton by-products for value addition;
- Increase transparency in the cotton sector, including on the full value of seed cotton, lint and seeds, and the opportunities and cost-benefit analysis to add further value;
- Promote financial and/or technical assistance from government or funders to add value to cotton by-products;
- Ensure government support for the establishment of cotton by-product processing businesses, for example by:
  - including by-products in national cotton sector development strategies, with action plans aiming to add more value to cotton;
  - implementing clear national policy guidance on the development of both the edible oil and meal production industries, with favourable tax regimes;
  - putting in place policy incentives to encourage investment (local and/or foreign direct investment) in or adoption of technologies to add value to cotton by-products; and
  - enforcing tariffs and taxes on imported oils and meals.
- Build capacity to establish well-organized industry groups (farmer associations/cooperatives, ginner associations, oilseed processor associations, inter-professional organizations and cotton boards);
- Promote South-South cooperation, including with countries such as Brazil, China, Egypt, India or Turkey.

This paper also provides a comprehensive overview of cotton by-products and their uses in African and other cotton-producing countries.

Chapter 1
Markets for cottonseed oil and cakes

Cotton field (© ITC)

About 35% of the global cotton lint production is traded internationally. Yet the global market for cotton by-products is very thin, as these goods are typically consumed where they are produced. This is also one reason there are no recognized benchmarks for international prices of cotton by-products.

Few international markets or price indications

The only indication of international market prices exists for cottonseed oil and, to a lesser extent, oilcakes. For all other cotton by-products, there are no international markets or comparable price indications.

The production of cottonseed is relatively low compared to other major oilseeds such as soybean, rape or sunflower. As a result, the evolution of prices for these oilseeds strongly influence the prices for cottonseed oils and cakes.

To better understand the market potential for cottonseed oil and cakes, this chapter examines the production and trade of cottonseed oils and cakes, as well as prices for oilseeds, vegetable oils and protein meals. As these are commodity prices, the chapter mainly refers to prices in the United States as reported by the United States Department of Agriculture (USDA).

Cottonseeds (© Shutterstock / Alf Ribeiro)

Cotton oil (© Shutterstock / Tolikoff Photography)

Cottonseed cake to feed animals (© Shutterstock / Dineshahir)

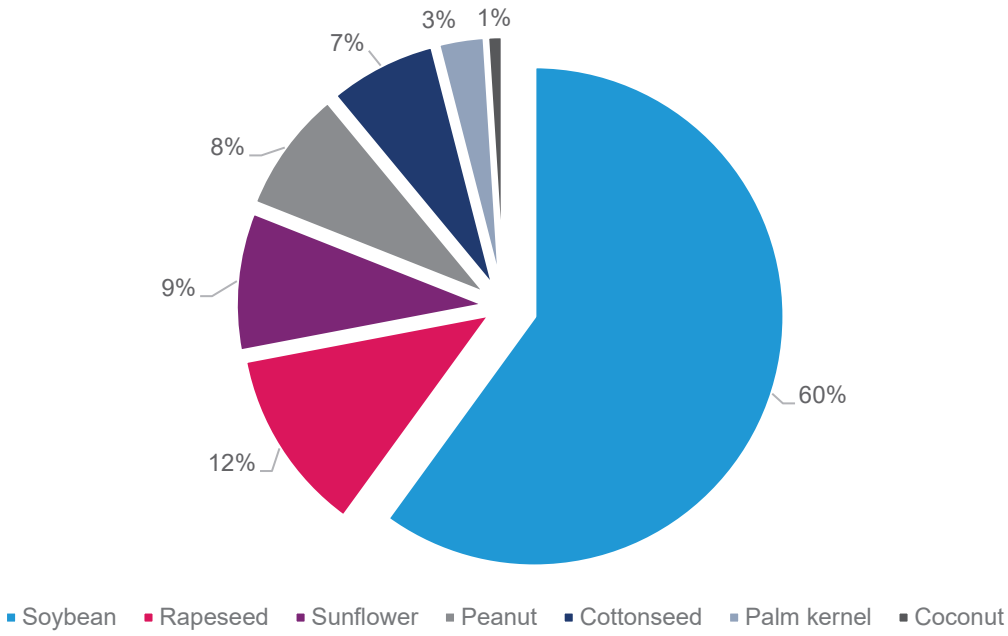
Shepard feeding his animal with cottonseed cake (© Shutterstock / Riccardo Mayer)

Production

Global production of the seven major oilseeds – soybeans, rapeseed, sunflower, peanut, cottonseed, palm kernel and coconut – averaged 585 million tons in the period 2016/17 through 2018/19. Cottonseed ranked fifth, averaging 42.5 million tons[1] (7%), behind soybean (350 million tons, 60%), rapeseed (72 million tons, 12%), sunflower (49.5 million tons, 9%) and peanut (46 million tons, 8%), followed by palm kernel (19 million tons, 3%) and coconut (6 million tons, 1%).

[1] According to statistics from the International Cotton Advisory Committee (ICAC), world production of lint averaged 23.8 million tons from 2015/16 through 2017/18.

Figure 1 Soybeans dominate oilseed production



Source: USDA.

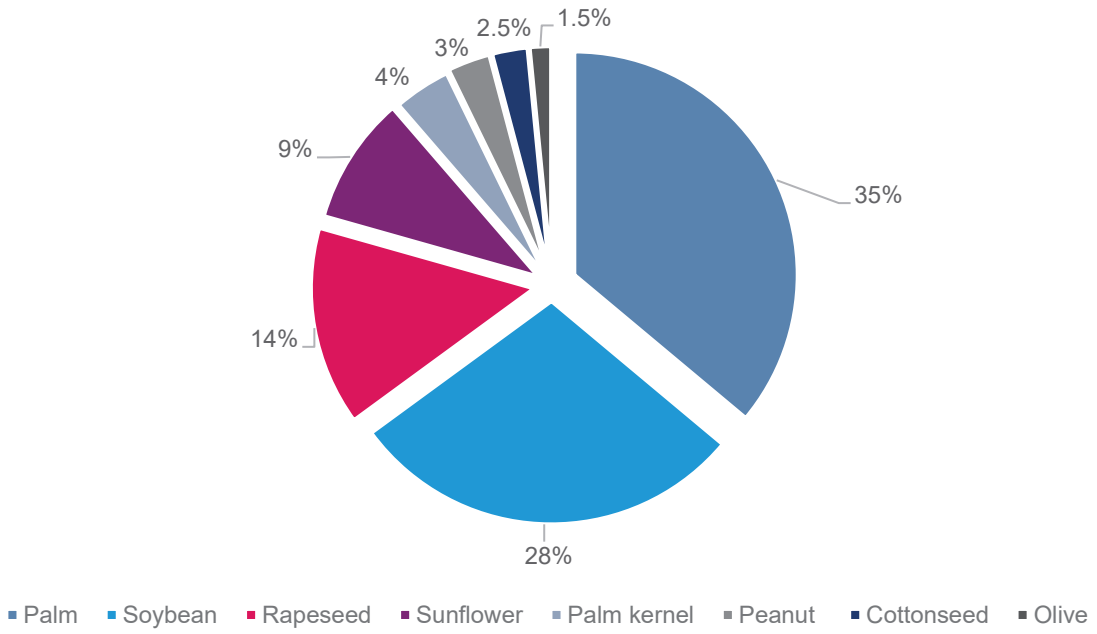
Ranked by oil content, cottonseeds are the lowest among the seven major oilseeds.[2] As such, production of cottonseed oil is relatively low compared to other vegetable oils.

Furthermore, cottonseed is also used as livestock feed, so not all the cottonseed produced is actually crushed. USDA data show that a yearly average of 32 million tons of cottonseeds, or 75% of the global production, were crushed in 2016/17 to 2018/19. As a result, the global production of cottonseed oil averaged 4.8 million tons, accounting for only 2.5% of the global production of the nine major vegetable oils, estimated at 197 million tons.

Palm oil (70 million tons) and soybean oil (55 million tons) dominate the world market.

[2] Cottonseed oil content is about 16%, compared to about 54% for sunflower, 50% for palm kernel and groundnuts, and 20% for soybean.

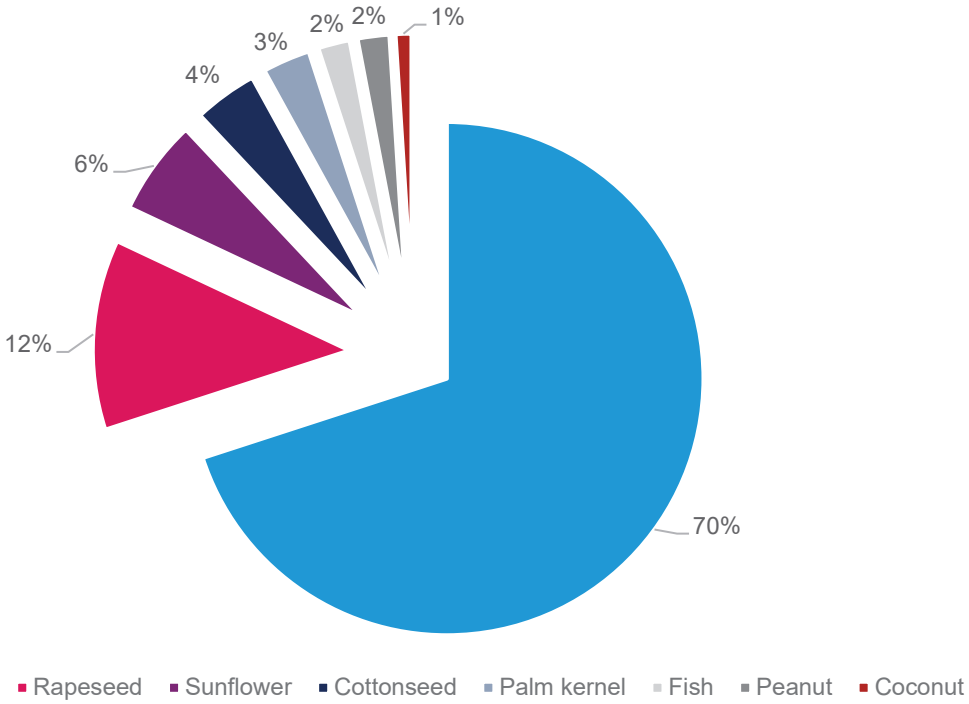
Figure 2 Palm and soybean are the leading vegetable oils



***Source*: USDA.**

The second most important cotton by-product coming from the seed is oilcake or protein meals that remain when the oil is extracted. From 2016/17 through 2018/19, global production of the eight major protein meals averaged 328 million tons. Cottonseed ranked fourth, averaging 14.5 million tons (4.5%), behind soybean (230 million tons, 70%), rapeseed (39 million tons, 12%) and sunflower (20 million tons, 6%).

Figure 3 Soybean and rapeseed are the top protein meals



***Source*: USDA.**

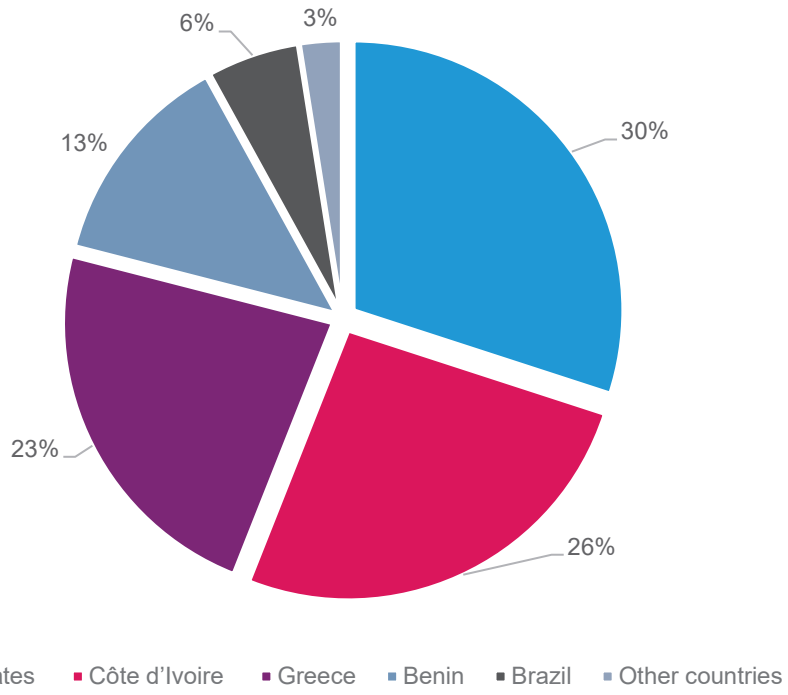
Global trade of selected cotton by-products

As previously noted, cotton by-products are essentially consumed in their respective domestic markets. In contrast, the share of cotton lint traded internationally averaged 35% of the global production from 2016/17 through 2018/19.[3]

Total exports of the seven major oilseeds averaged 173 million tons, or 30% of global production, over the three years from 2016/17 through 2018/19, according to USDA data. Soybeans dominated the market, (149 million tons or 86%), followed by rapeseeds (15 million tons or 9%). Exports of cottonseeds averaged 850,000 tons over the three-year period, only 0.5% of the estimated global trade.[4]

Cottonseed exports (excluding for sowing) topped 1 million tons in 2019, for a total value of $200 million.[5] Five countries accounted for 95% of the total: the United States (301,000 tons), Côte d'Ivoire (259,000 tons), Greece (232,000 tons), Benin (129,000 tons) and Brazil (53,000 tons). The largest importers were the Repubic of Korea (154,000 tons), Italy (136,000 tons), Mali (131,000 tons), Saudi Arabia (123,000 tons), Mexico (100,000 tons), Japan (93,000 tons) and Burkina Faso (87,000 tons).

Figure 4 United States, Côte d'Ivoire lead cottonseed exports



***Source*:** ITC Trade Map.

[3] Exports of lint averaged 8.2 million tons over this three-year period, according to ICAC.

[4] Exports of soybeans accounted for 43% of the average production, and exports of rapeseeds for 20% of the production.

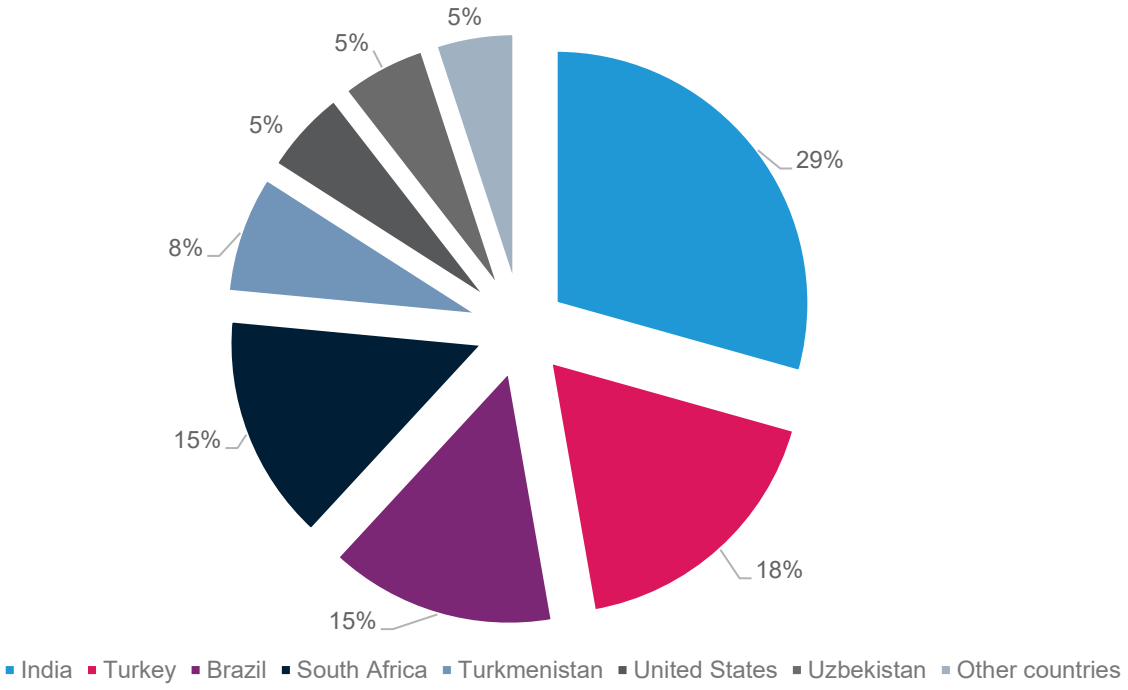
[5] ITC Trade Map.

Exports of the nine major vegetable oils averaged 82 million tons, or 42% of global production, in 2019. Exports of palm oil (50 million tons) and soybean oil (11 million tons) accounted for 61% and 13% of the market, respectively.[6] Exports of refined cottonseed oil were marginal, at an estimated 100,000 tons.[7]

Exports of the eight major protein meals averaged 90 million tons, or 27% of global production. Exports of soybean meal (66 million tons) accounted for 73% of the global market. Exports of cottonseed meal are marginal, at about 400,000 tons.

Total exports of cotton linters amounted to 158,000 tons in 2019 for a total value of $98 million.[8] The top exporters were India (46,000 tons), Turkey (28,000 tons), Brazil (23,000 tons), South Africa (23,000 tons), Turkmenistan (12,000 tons) and the United States and Uzbekistan (9,000 tons each).The largest importers were China (88,000 tons), Japan (25,000 tons) Spain (15,000 tons) and Bangladesh (7,500 tons).[9]

Figure 5 India and Turkey paced cotton linter exports in 2019



***Source*:** ITC Trade Map

Evolution of oilseed and vegetable oil prices

As most edible oils are close substitutes for each other, their markets are highly integrated. This includes the market for cottonseed oil, of which only a low percentage of global production is traded internationally. As a result, cottonseed prices historically follow the prices of other major oilseeds, and cottonseed oil prices follow those of major other vegetable oils.

[6] Exports of palm oil accounted for 72% of the average production, and exports of soybean oil for 20%.

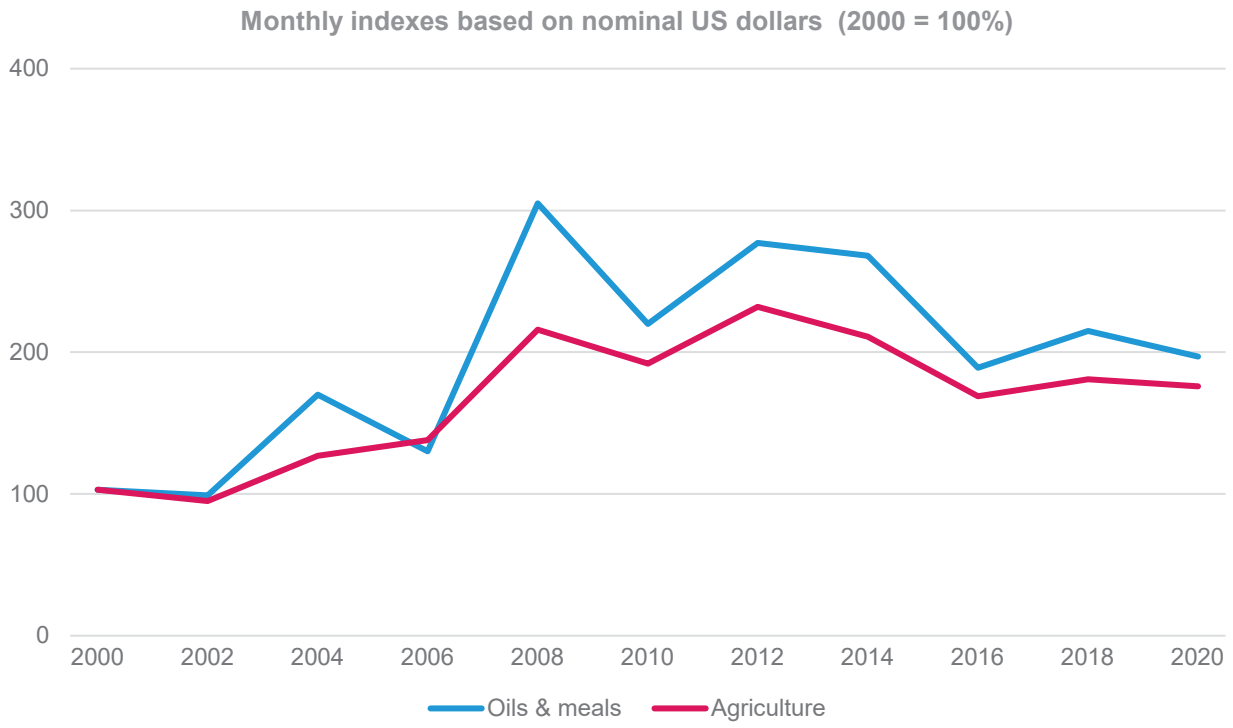
[7] About 20,000 tons of crude cottonseed oil (exporters: Kazakhstan and Turkmenistan) and about 100,000 tons of refined cottonseed oil (top exporters: United States, Benin; top importers: Mexico, Nigeria).

[8] ITC Trade Map. Average price $0.68/kilogram, up from $0.54/kilogram in 2016.

[9] *Ibid*.

In addition, changing production and consumption patterns influence the relative prices of edible oils.[10] Prices for vegetable oils and meals follow those of other agricultural commodities.

Figure 6 Oil and meal prices mirror commodity price trends



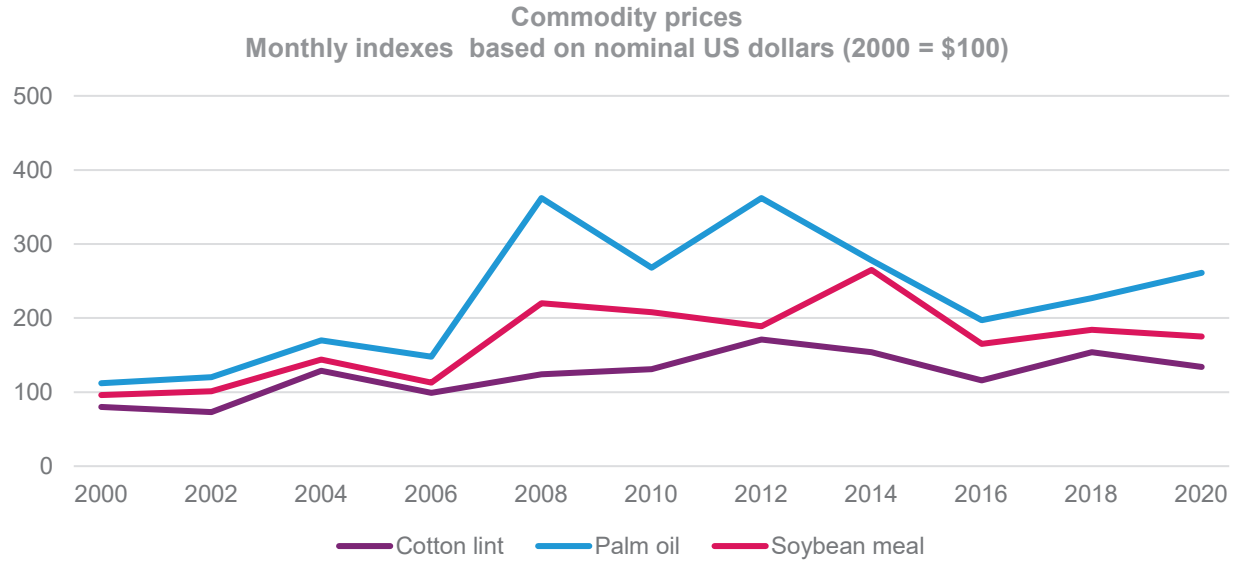
***Source*:** World Bank.

Prices of palm oil and soybean meal have increased faster than cotton lint since 2000. According to World Bank commodity price forecasts in April 2020, cotton prices in constant 2010 dollars are expected to increase from $1.72 per kilogram in 2019 to $2.10 per kilogram in 2030.

Meanwhile, palm oil prices are forecast to climb 19% in this period, while the price of soybean meal is expected to rise 4%. This should translate into relatively higher cottonseed prices, as cottonseed oil would increase along with palm oil prices, as both are potential substitutes.

[10] For example, the substitution by farmers of soybean meal with maize for animal feed, or the substitution of soybean oil with palm and rapeseed oils for human consumption.

Figure 7 Lint price trails palm oil and soybean meal prices

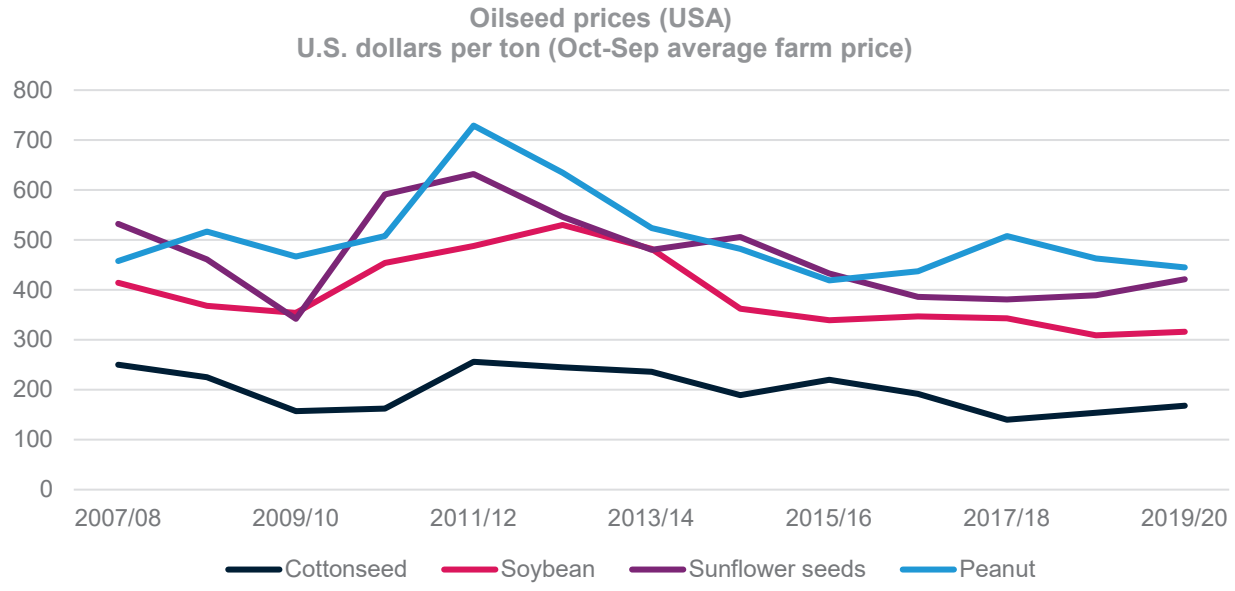


***Source*:** World Bank.

As there is no recognized benchmark for the international prices of cotton by-products, the trading prices in the US market can give an indication of price development. The farm price of cottonseeds in the United States is lower than those of soybeans, sunflower seeds and peanuts.

The farm price for a ton of cottonseeds fluctuated from $140 to $220 in the last three seasons. It stood at about $168 a ton in the marketing season 2019/20.[11]

Figure 8 Cottonseed is one of the lowest-priced oilseeds

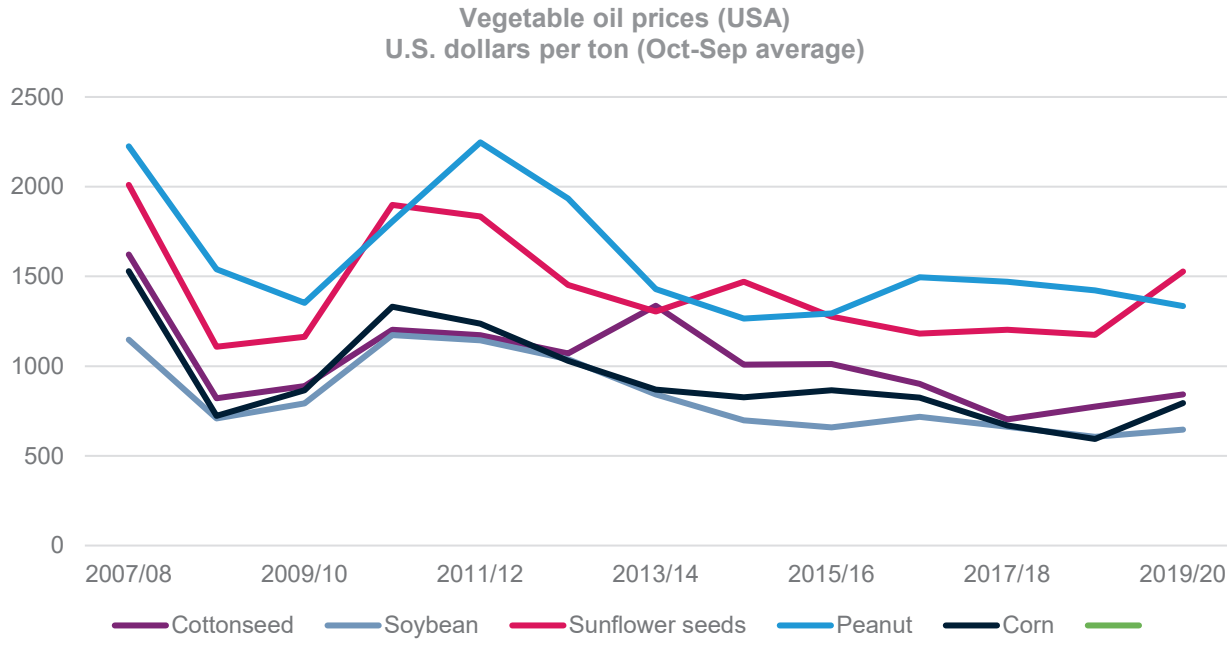


***Source*:** USDA.

[11] Average monthly farm prices fell from a peak of $356 per ton of seed cotton in January 2012 to a low of $157 in November 2017, according to the USDA.

Cottonseed oil is generally traded at a lower price in the United States than peanut and sunflower oils. It has a similar price to corn oil and it trades at a higher price than soybean and palm oils.

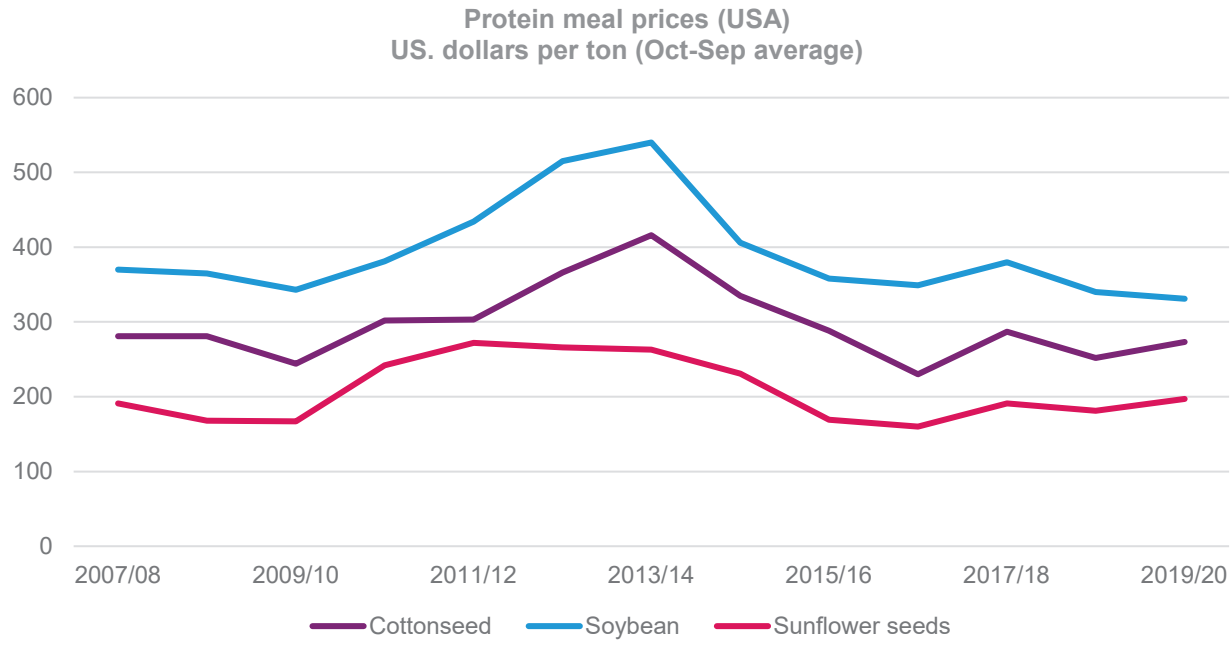
Figure 9 Cottonseed oil price tops soybean and corn oil prices



***Source*:** USDA.

Cottonseed meal trades lower than soybean meal, but higher than sunflower seed meal, averaging around $300 a ton in the US market.

Figure 10 Cottonseed meal averages $300 a ton in US market



***Source*:** USDA.

While cottonseed prices have not shown a strong upward trend in recent years, cottonseed oil and cakes still provide an important revenue stream for oil mills and cotton companies that also crush the seeds. As the same process is used to produce oil and cake from the cottonseed, their market potential must be considered together.

Cottonseed cakes draw a much higher price than soybean or sunflower seed cakes due to their relatively high protein content. They are therefore the preferred fodder for animal husbandry and cattle farms.

Demand for animal feed and especially cottonseed cakes is growing in Africa. Oil mills and cotton companies must increase the crushing rates of cottonseed and improve the quality further to meet this demand and benefit from relatively good prices (compared to other oilcakes). As oilcake is a coproduct of the seed, together with oil, the oil will also need to be marketed.

Potential exists to market and promote cottonseed oil in local markets. This oil is an import-competing crop, as all sub-Saharan African countries are net importers of edible oil (mostly palm oil). Cottonseed oil is more nutritious than imported palm oil, so there is potential for both marketing and branding. Annex 1 offers more information about cottonseed oil and cakes.

Chapter 2
How does Africa use cotton by-products?

Cotton harvest (© ITC)

Production of cottonseed is directly linked to the production of lint, as both are coproducts of the ginning operation. As a result, the top producers of lint, or raw cotton, are also the top producers of cottonseeds.

India outpaced China as world's largest cotton producer from 2014/15 to 2017/18. The United States is the third-biggest producer and the No. 1 exporter of lint. Brazil overtook Pakistan as the fourth-largest producer in 2017/18.

The percentage of unprocessed cottonseeds that are used for cattle feed[12] varies across countries. Feeding cattle directly is a missed opportunity, as no oil is produced from the seeds. However, high protein cake or meal could still be fed to cattle.

The eight largest cotton-growing countries produced more than 21.7 million tons of lint in 2016/17 through 2018/19. India overshadows all other countries in terms of its planted cotton area, with almost 12 million acres planted. It is also the biggest producer of line, oilseeds and meal.

[12] Whole cottonseeds are increasingly used in the dairy industry, because adding them to the diet of early-lactation cows usually boosts energy intake, which often leads to bigger milk yields.

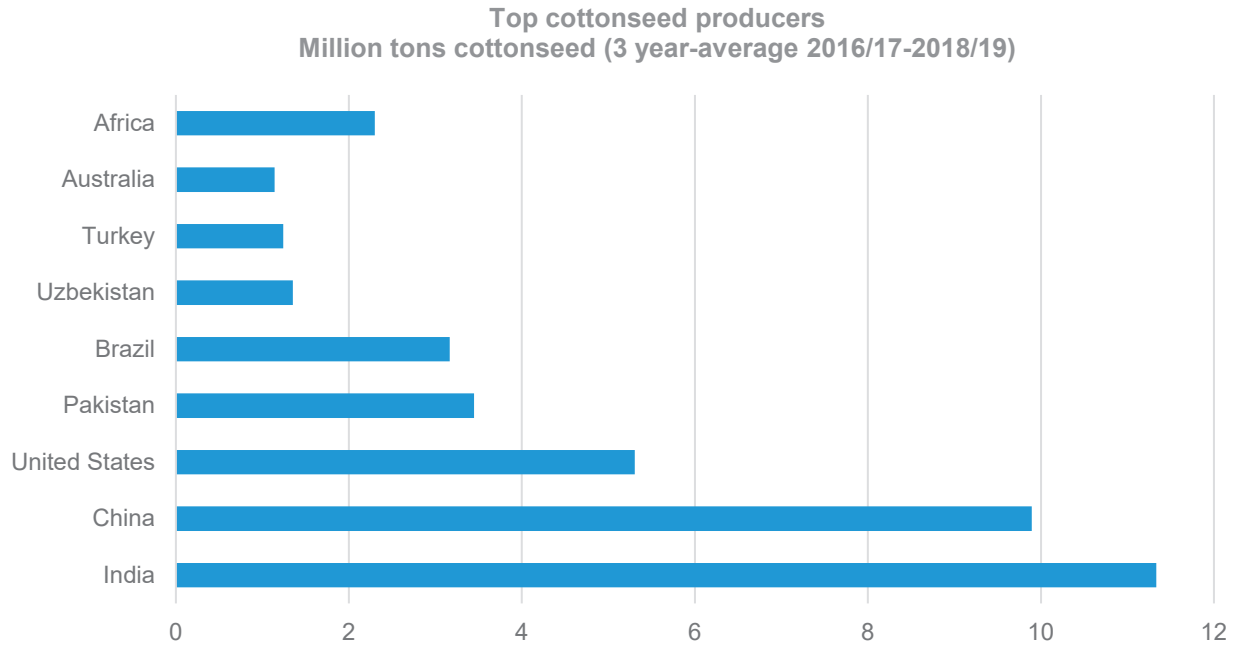
Table 1 India, China and United States are top lint producers

	Cotton area (000 hectares)	Lint (000 tons)	Oilseeds (000 tons)	Oil (000 tons)	Meal (000 tons)
India	11,893	5,855	11,334	1,213	3,939
China	3,272	5,610	9,894	1,259	3,749
United States	4,157	4,099	5,303	262	789
Brazil	1,244	2,105	3,165	461	1,368
Pakistan	2,495	1,709	3,446	465	1,409
Turkey	467	824	1,242	232	679
Australia	470	807	1,142	110	319
Uzebekistan	1,119	743	1,351	302	594

***Note*:** Three-year averages (2016/17–2018/19).

***Source*:** ICAC and USDA.

Figure 11 Africa is sixth-biggest producer of cottonseeds



***Source*:** USDA.

African cotton producers: Similar traits and challenges

The status of cotton by-products is very similar across all producing countries in sub-Saharan Africa, as they share common characteristics and must grapple with the same limitations and challenges.

Desk review and stakeholder interviews conducted in 2018 show little evolution from findings of previous studies on the African oilseed sector commissioned by the World Bank (2009) and USAID (2010).

Cottonseed oil and cake represented up to 30% of the total value of seed cotton in sub-Saharan Africa. Growing demand for edible oil and animal feed has bolstered cottonseed prices, so the contribution of cottonseed by-products to the overall value of cotton fibre and seed has increased in the last decade.

With few exceptions,[13] cotton is a smallholder crop in Africa. As seed cotton is sold to ginning companies or to traders, the ginners own both the lint and the cottonseeds.

The only by-products that are used are cottonseeds, oil, cake, meal and, to a lesser extent, linters and ginning (lint-cleaner) waste. The contribution of cottonseed to the total value of cotton depends on the ginning ratios, the lint and seed prices.

Fewer than 10% of cottonseeds are treated for use as planting seeds. Most oilseeds are sold to oil crushers in the domestic market or in neighbouring countries. Whole cottonseeds can also be sold as feedstuff to the livestock sector.

All sub-Saharan African countries have an oilseed-processing industry, with varying mixes of the three types of processing (artisanal, semi-industrial and industrial) competing on the domestic market with imports of edible oil and meal. The number of oil processors varies across countries, from one to about 100, and few are integrated with ginning.

Small-scale traditional mills produce crude or semi-refined oil of lower quality that is cheaper than the refined oil processed by large-scale modern mills. Virtually all cottonseed oil produced is used for human consumption in the domestic market.

Cotton meals and cakes are sold for animal feed. Demand for whole cottonseeds and cottonseed meal is much stronger in countries with a large cattle population, such as the Sahelian countries.

Linters are generally exported due to the absence of local value-added industries.[14] Gin motes are mostly treated as waste products. Some ginners sell lint-cleaner waste.

There are no commercial uses for cotton stalks. Farmers usually cut and dry the stalks before burning them. Stalks are sometimes used as fuel, as cattle feed or to make fertilizer.

Cottonseed prices are higher in producing regions or countries that are landlocked. This is due to the high cost of transporting imported edible oils into these areas, which makes them more expensive.

The value of cotton by-products varies according to:

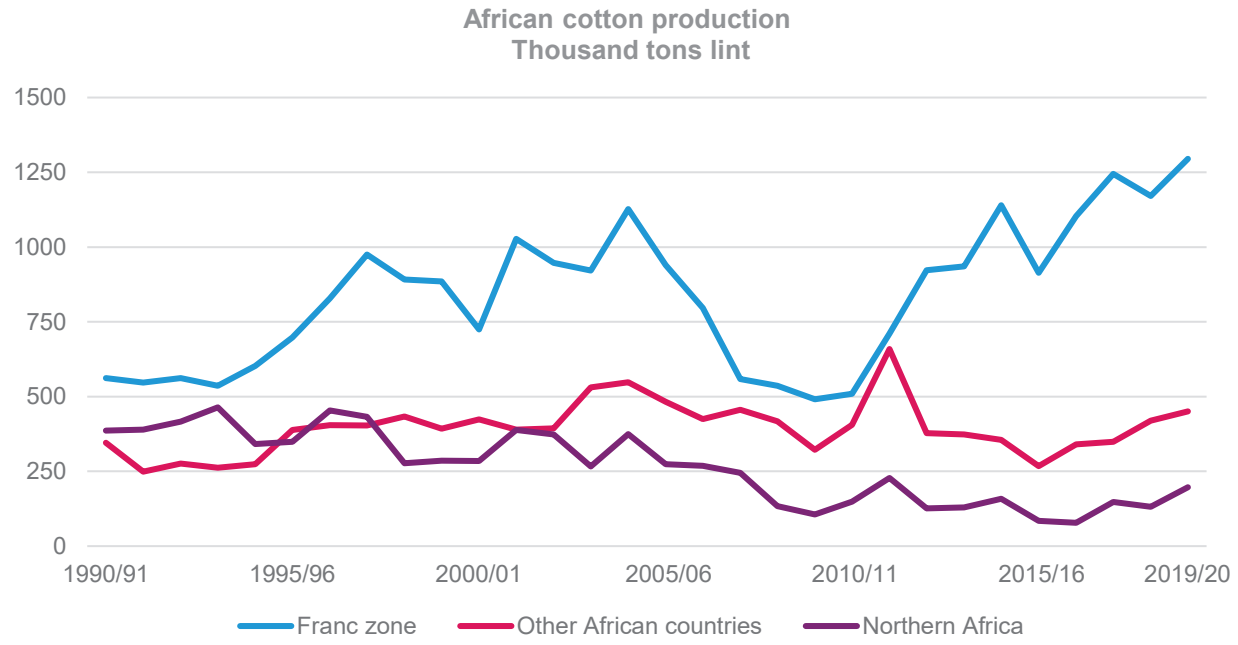
- prices and market conditions;
- location of cotton production;
- demand by livestock sector/dairy industry;
- availability of competing oilseeds, oil and meals;
- ginning and seed-crushing technologies used, which affect the processing rates.

Despite the overall similarities, beyond the common features, there are differences between countries that are mostly related to the structure of the cotton sector.

[13] Ethiopia and South Africa.

[14] According to ITC Trade Map, African countries exporting linters are South Africa (9,042 tons in 2018); Zambia (5,271 tons in 2018); Malawi (1,096 tons in 2017 and 5,275 tons in 2014); United Republic of Tanzania (four-year average 950 tons; only 10 tons in 2018).

Figure 12 Evolution of cotton production in Africa



***Source*:** ICAC.

Western and Central Africa: Top producers

Eight countries of the 14-nation CFA franc zone produce cotton, including the four largest producers in Africa (Mali,[15] Burkina Faso, Benin and Côte d'Ivoire) as well as Cameroon, Togo, Chad and Senegal. Franc zone[16] countries account for more than 70% of African cotton production.

The organizational model of the cotton sector has been successful in promoting cotton production. Strong government support has been a key driver in the development of cotton in the franc zone. The cotton production support system fostered agricultural innovation in rural areas.

Parastatal or private cotton companies have played a role as both economic operators and in promoting social development in cotton production zones. Vertically integrated cotton firms ensured the coordination of the subsector, from providing inputs to producers to collecting seed cotton, ginning and marketing lint and seeds, and processing oilseeds. Cotton companies assisted in the formation and training of cotton producer organizations or cooperatives.

While private entry has been allowed to some extent in Benin, Burkina Faso, Chad, Côte d'Ivoire and Senegal, in practice markets remain strongly regulated. Ginning companies have never been allowed to compete for the purchase of seed cotton. Governments retain a share in the capital of most companies. There is only one ginning company in Cameroon, Chad, Mali, Senegal and Togo. National cotton producer unions or cooperatives have a minority share in most cotton businesses.

Cotton has been an engine for development in rural areas, where it has helped improve incomes, livelihoods and access to social facilities, with positive impacts on poverty and food security. Unlike their counterparts in East and Southern Africa, cotton producers in franc zone countries benefit from a pan-seasonal and pan-

[15] Mali ranked 11th in the world in 2017/18.

[16] The CFA franc zone includes 14 sub-Saharan countries sharing a common currency, the CFA franc, which is pegged to the euro by a fixed parity (EUR 1 = 655,957 XOF).

territorial minimum guaranteed price for seed cotton announced before planting. The price of inputs delivered on credit is announced at the same time.

Until the mid-1980s, most cottonseed went to waste with no value attached. Until the 1990s, the development model for the national cotton sectors in Western and Central Africa integrated a large-scale oil processing plant within the parastatal cotton company. Oil-processing activities were privatized in most countries.

Cameroon and Chad[17] are the only African countries where the initial structure of the cotton sector has remained unchanged, with oil processing fully integrated with ginning in the cotton company.

Cotton oil constitutes the main source of edible oil for the populations in the cotton areas in Western and Central African countries.

The wholesale and retail markets for oil and meal are generally liberalized and competitive, with prices fluctuating seasonally. In both Mali and Burkina Faso, large modern processing plants face increasing competition from low-cost Indian- or Chinese-manufactured pressing equipment.

Whole cottonseeds are increasingly used as cattle feed in landlocked Sahelian countries, thus limiting the possibility of value addition in terms of oil and cake production.

Farmers, along with other stakeholders, help decide the prices of seed cotton and cotton inputs. However, the value of the seed and the by-products derived from it are not or hardly factored into the price for seedcotton. Seedcoton prices, therefore, mainly refelect the projected value of the lint but are not very trasparentwith regard to the value iof the seed.

Formal cotton interprofessions comprising producer and ginner organizations have been established in Benin, Burkina Faso, Côte d'Ivoire and Mali. In the four other franc zone countries, national producer organizations are involved in the pricing negotiations.

[17] Oil processing was briefly privatized in Chad in 2000, but returned to Société cotonnière du Tchad, also called Cotontchad, after privatization failed. In 2018, the enterprise was privatized to OLAM, a global leading agribusiness company, trading more than 45 agri-commodity products including edible oil, and the largest private ginner in the world (according to its website).

Table 2 Mali and Burkina Faso have dozens of oil mills

Country	Cotton companies	Interprofession	Farmer representataive bodies	Oil mills
Mali	1	Interprofession du coton du Mali (Compagnie malienne de développement des textiles + Confédération des sociétés coopératives de producteurs de coton du Mali)	Confédération des sociétés coopératives de producteurs de coton du Mali	+/-100
Burkina Faso	3	Association interprofessionnelle du coton du Burkina Faso (Association professionnelle des sociétés cotonnières du Burkina Faso + Union nationale des producteurs de coton du Burkina Faso)	Union Nationale des Producturs de Coton du Burkina Faso	+/-60
Benin	4	Association interprofessionnelle du coton du Bénin (Conseil national des égreneurs de coton du Bénin + Fédération nationale des coopératives villageoises de producteurs de coton du Bénin)	Fédération nationale des coopératives villageoises de producteurs de coton du Bénin	2
Côte d'Ivoire	6	Intercoton (Association professionnelle des sociétés cotonnières de Côte d'Ivoire + Fédération des unions des sociétés coopératives des producteurs de la filière coton de Côte d'Ivoire + Association des triturateurs de graines oléagineuses de Côte d'Ivoire)	Fédération des unions des sociétés coopératives des producteurs de la filière coton de Côte d'Ivoire	2
Cameroon	1		Confédération Nationale des Producteurs de Coton du Cameroun	1
Togo	1		Fédération nationale des groupements de producteurs de coton du Togo	1
Chad	1		Union Nationale des Producteurs de Coton du Tchad	1
Senegal	1		Fédération nationale des producteurs de coton du Sénégal	1

Eastern and Southern Africa: Concentrated and competitive

In declining order of lint production in 2017/18, the largest cotton-producing countries in Eastern and Southern Africa are the United Republic of Tanzania, Ethiopia, Zimbabwe, Zambia, Uganda, South Africa, Mozambique and Malawi.

The Eastern and Southern African cotton sectors are concentrated and competitive, as ginners and their agents can compete to buy seed cotton from farmers,[18] (except in Mozambique, which operates local monopolies in concession zones).

Competition for volume, which is critical for ginners to break even, undermines the coordination needed to provide services such as input credit, extension, quality control and research. This tends to generate suboptimal yields and, hence, relatively low incomes. Competition also affects seed cotton and lint quality, which limits the price that ginners can pass on to farmers.

The producer price is determined almost entirely by the international price of lint and the domestic price of cottonseed prevailing at the beginning of the marketing season. Setting the price before marketing increases producer price volatility and fluctuations in production.

Price elasticity of cotton production is very high. Because the producer price is not set and guaranteed before planting – like in Western and Central African countries – Eastern and Southern Africa cotton farmers base their decision to plant on the prior year's price.

Smallholder farmers in Eastern and Southern Africa are the most exposed to the risk of cotton price volatility and are among the least protected in the world.[19]

The volatility of cotton prices has a major impact on cotton production in Eastern and Southern Africa. Many farmers enter and exit cotton production depending on prevailing prices, so they fail to amass the knowledge and skills that would lead them to increased yields and profits.

Ginners drive the Eastern and Southern African cotton sectors. Farmers are less organized and their associations are much weaker compared to the franc zone countries.

As cotton production is much lower and more volatile than in Western and Central African countries, the quantity of by-products is not sufficient and is too unstable to achieve economies of scale and to justify investments into large-scale and modern processing facilities.

Cottonseed oil production accounts for a rather small proportion of local edible oil consumption.

Cottonseeds are occasionally fed to livestock. This is not a common practice, however, because the relatively small production of seeds tends to be reserved for oil processing.[20]

The production of cotton oilseeds[21] in the table below has been calculated using ICAC data on lint production and the estimated seed-to-lint ratio for each African country. There are no reliable data on cotton oil and meal production.

[18] With a risk of side-selling by producers to ginners who have not prefinanced the inputs.

[19] Compared to India, China, the United States, Pakistan and West and Central Africa countries.

[20] In contrast, all cotton oilseeds are used as cattle feed in South Africa (the price in early 2019 was around 300 ZAR/ton or just over $200).

[21] USDA-published data on cotton oilseeds production are inconsistent with data on lint production, which are more reliable.

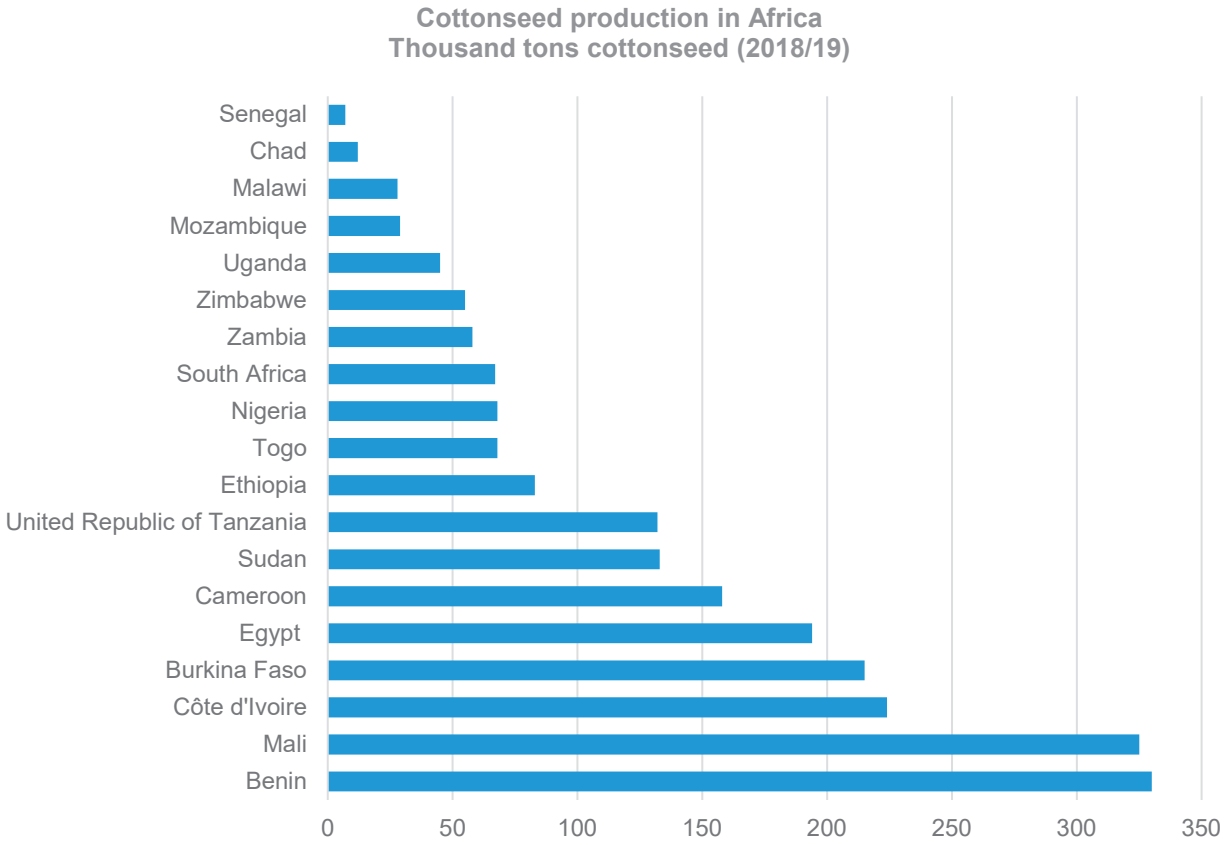
Table 3 Benin and Mali lead regional lint and oilseed production

	Cotton area (000 hectares)	Lint (000 tons)	Oilseeds (000 tons)
Western and Central Africa			
Benin	656	295	330
Mali	698	276	325
Côte d'Ivoire	392	198	224
Burkina Faso	646	189	215
Cameroon	204	133	158
Togo	180	56	68
Chad	60	9	12
Senegal	22	6	7
Nigeria	250	51	68
Southern and Eastern Africa			
United Republic of Tanzania	420	81	132
Ethiopia	78	57	83
South Africa	42	48	67
Zambia	197	47	58
Zimbabwe	121	45	55
Uganda	81	35	45
Mozambique	140	21	29
Malawi	86	21	28
Kenya	13	2	
Northern Africa			
Sudan	142	104	133
Egypt	180	111	194

***Note*:** Data from 2018/19.

***Sources*:** ICAC, USDA, stakeholders' interviews, consultant's calculations.

Figure 13 Benin and Mali are top African cottonseed producers



***Source*:** Consultant's calculations.

Constraints and challenges in developing cotton by-products

All sub-Saharan African countries face similar obstacles to the development of the cotton by-product value chain. Markets for semin and refined oil as wel as cakes and meals are poorly understood and prices are not well documented. As a result, there is little transparency about the way the value of cottonseed is accounted for in seed cotton prices.

Policies that influence the prices of seed cotton, cottonseed, oil and cake affect the performance of the cotton sector. Taxes on by-products sold in local markets and tariffs on imports affect competitiveness.

The oilseed sector is poorly integrated into the cotton sector. No crushing firms in Africa, excluding Côte d'Ivoire,[22] are members of cotton interprofessional organizations or cotton boards.

Moreover, mills using traditional pressing process aren't efficient in terms of oil extraction rates. They produce poor-quality crude or semi-refined oils, but at a lower cost and at a cheaper price than refined oil processed by mills using solvent-extraction technologies.

[22] The Association des triturateurs de graines oléagineuses de Côte d'Ivoire is a member of the sectoral professional association, Intercoton.

Weak enforcement of food safety and quality norms for cotton by-products for human and animal consumption can create unfair competition between artisanal or semi-industrial oil mills and large industrial modern mills.

Like other edible oils produced domestically, cottonseed oil suffers from fierce and often unfair (smuggling) competition from imported oils, mostly palm oil (crude, semi-refined or refined).

The presence of gossypol in cottonseeds is a major impediment to human and animal (nonruminants) consumption, as it is toxic to both. Although there are solutions to remove this yellow pigment[23] – for instance, refining the oil removes gossypol almost completely – the oil-processing equipment needed to reduce gossypol content in refined cottonseed oil is capital-intensive and not easily accessible in Africa.

Gossypol is non-toxic for ruminants. To use cottonseed meal as fodder for nonruminants, gossypol would need to be extracted through a chemical process. Appendix provides more details.

Cottonseed has a relatively low oil content compared to most other oilseeds. This is partly because research efforts focused on maximizing the quantity (ginning outturn) and quality of lint, rather than the oil or meal content.

Technologies for processing by-products to add value to cotton exist but they are not well-known or readily available in Africa. All actors in the cotton value chain (farmers, ginners, crushers, potential investors) lack knowledge about the potential uses of cotton by-products – especially stalks – and the value they could add. As a result, local markets for cotton by-products other than oil and meal are underdeveloped.

The lack of linkages among the cotton, oil and livestock sectors is an obstacle to the wider use of agribusiness by-products.

Eastern and Southern African countries face unique barriers

In addition to challenges listed above, Eastern and Southern African countries must contend with other obstacles to the development of their cotton by-product value chain.

Limited and volatile cotton production hinders the development of downstream activities in the cotton value chain. Consequently, fluctuations in supply may deter potential investment decisions in the sector. Also, low production aggravates overcapacity and prevents economies of scale, increasing production costs.

The relative weakness of farmer organizations compared to Western and Central African countries makes it difficult to create a cost-effective cotton by-product supply chain.

Inflation rates and interest rates in Eastern and Southern African countries are usually substantially higher than in franc zone countries. That puts companies in Eastern and Southen Africa at a disadvantage, as it is more difficult for them to obtain capital and invest in cotton by-products.

[23] Gossypol toxicity limits the use of cottonseed in animal feed.

Chapter 3
Challenges and opportunities to develop cotton by-products

Local women working in a cotton farmer (© ITC)

Cotton lint is one of the key commodities for generating household incomes, creating employment and easing poverty in sub-Saharan African countries.

Consumer demand for oilseed products is growing across the continent. This includes edible oils for human consumption and animal feeds for dairy, livestock and poultry sectors.

Cotton by-products can help alleviate poverty

Cottonseed oil and cake typically represent up to 30% of the total value of seed cotton. Despite their numerous and diverse potential uses, by-products including cottonseed, the coproduct of lint, are underused, or even neglected, in Africa. If value addition activities could be expanded and fully exploited, cotton by-products could contribute much more to economic growth, employment and poverty alleviation.

Processing gin waste into fuel pellets could provide a renewable source of energy that could become a viable source of revenue for cotton gins.

Cottonseed production in sub-Saharan Africa, estimated at about 2.2 million tons today, is the equivalent of 400,000 tons of oil based on an optimized extraction rate of 18% and 500,000 tons of protein (23%).

The use of cotton oil to produce biofuel is unlikely to be economically viable as long as sub-Saharan African countries are not self-sufficient in edible oil.

With a total cotton area of about 4.5 million hectares in sub-Saharan Africa, more than 10 million tons of biomass could be produced from cotton stalks.

All countries on the continent, especially those in Western and Central Africa, need organic fertilizer to improve soil fertility and ensure production sustainability in the context of climate change.

Products made from cotton stalks (biomass briquettes/pellets and mushrooms) could help address the policy priorities in many African countries, creating income opportunities for farmers, small-scale business in rural areas (including women) and entrepreneurs that invest in valorizing by-products. Growing mushrooms would also contribute to improving nutrition for many stakeholders, especially farmers.

Biomass fuels respond to policy priorities on forest conservation, the reduction of carbon-dioxide emissions and substitution for wood charcoal and fossil fuels.

Cotton agribusiness by-products could improve the quality of livestock in sub-Saharan Africa, especially in the arid and semi-arid agroecological zones, to meet increasing demand amid growing population and urbanization rates.

Cottonseed oil can replace oil imports

Global per capita consumption of edible oil averaged 19 kilograms in 2012–14, according to the Organisation for Economic Co-operation and Development and the Food and Agricultural Organization of the United Nations (2015). They predicted that total consumption would grow by 1.8% a year in 2015–2024.

Per capita consumption in sub-Saharan Africa is forecast to rise to 10.3 kilograms from 9.8 kilograms. Total consumption is expected to increase at an annual rate of 3.2%, to exceed 12 million tons of edible oil by 2024.

Table 4 Sub-Saharan Africa consumes about 5% of world's edible oil

Countries	kiloton/year (2012-2014)	kilogram/capita/year (2012-2014)	% growth/year (2015-2024)	kiloton/year (proj. 2024)	kilogram/capita/year (proj. 2024)
Developed	48.8	25.8	0.13%	50.3	26
Developing	118.7	17.5	2.4%	160	20
World	**167.5**	**19.1**	**1.81%**	**210.4**	**21**
United States	14.7	39.2	0.87%	16	39.9
European Union	22.5	24	-0.86%	21	21.5
China	31.3	22.2	1.73%	38.8	26.3
India	18.9	14.8	3.15%	27.3	19
Sub-Saharan Africa excluding South Africa	**8.9**	**9.8**	**3.16%**	**12.4**	**10.3**
South Africa	1.25	22	2.79%	1.6	23.4
Northern Africa	3.5	20.1	1.96%	4.5	22.2

***Source*:** Organisation for Economic Co-operation and Development and the Food and Agriculture Organization of the United Nations.

No country in sub-Saharan Africa is self-sufficient in edible oil.

The oil content in cottonseed is lower than in most oilseeds. In addition, use of the expander-press method[24] to extract oil limits both the quantity and the quality of cottonseed oil production. With this traditional method, 100 kilograms of cottonseed produce just 10 litres of oil, which is at least half of the potential with modern technologies.

The application of tariffs and other taxes on imported oils is a major challenge for the regulation of liberalized oil markets. African cottonseed oil and other edible oils face considerable competition from South Asian palm oil, which is often smuggled or imported without paying tariffs designed to protect domestically produced oils.

Competition from imports has less effect on edible oil prices in landlocked regions or countries, where demand for cotton meals is also generally stronger.[25]

Cottonseed oil is highly nutritious and healthier than palm oil, as it consists of 70% unsaturated fatty acids. Palm oil is highly saturated in fatty acids.

The oil produced by small industrial and artisanal mills is less refined than oils processed in large industrial mills. As long as basic food safety requirements are met, however, consumers with limited incomes are willing to accept the lower quality of unrefined and semi-refined oils because they cost less.

For example, Ethiopia, the largest exporter of sesame oilseeds,[26] also imports large quantities of palm oil, which is widely used for cooking because its price-to-quality ratio is superior compared to domestically produced oils, including cottonseed oil.

Yet cottonseed oil can be successfully branded and promoted, and fetch a premium over imported palm oil. In Burkina Faso and Cameroon, for instance, refined cottonseed is preferred over palm oil for frying.

Cottonseed oil has the potential to replace some palm oil imports in African cotton-producing countries. However, even if seed cotton production increases and better technology results in a higher oil extraction rate, domestic production of cottonseed alone is unlikely to fill the gap between supply and demand.[27]

Farmers could boost income with cotton by-products

The market for cotton by-products is growing, which means they could offer cotton growers an important complementary source of revenue.

However, few African farmers own cottonseed,[28] as seed cotton is sold to ginners. As a result, they know little about the potential uses of the cottonseed produced at the gin and are unaware of the cottonseed price or the value of by-products such as oil and meal. Farmers are generally at a disadvantage when it comes to price negotiations because they lack access to the same information as ginners and oil millers.

Cotton stalks are the only by-product that could be valorized at the farmer level. Cotton stalk-based goods provide for an opportunity to create new sources of income for small-scale farmers.

Encouraging farmers to add value to their cotton by moving into by-products creates resilience against price and weather shocks, as well as additional income that can be earned between growing seasons. Farmers

[24] This traditional method of cottonseed oil extraction uses a circular mortar or more advanced technology, such as a hydraulic press or a screw press (expeller). The cotton seeds may be dehulled, cracked, dried or heated before being fed into the press. Mechanical extraction is not very efficient, and up to 20% of the seed oil may remain in the pressed cake, depending on the technology used.

[25] Inland transportation costs are a major component in the price of oil.

[26] Sesame is the second-biggest source of export earnings in Ethiopia after coffee.

[27] The potential cottonseed oil production of Mali, the largest producer in Africa, estimated at 65,000 tons with an optimized oil extraction rate of 18%, would represent 44% of the national edible oil consumption (estimated at 150,000 tons based on an average consumption of 8 kilograms per person).

[28] To own the seeds, farmers must own a gin or to have their production toll ginned.

can use cotton stalks as a source of fuel for their households, saving on expenses and/or preserving forest wood. They can also use cotton stalks as a source of organic fertilizer to improve soil fertility.

Converting cotton stalks into briquettes or pellets or using them to grow mushrooms can be a low-capital and profitable multifamily cottage activity. Farmers can invest directly in the production of briquettes/pellets or earn extra money by selling chipped stalks to entrepreneurs. However, briquette and pellet plants require a supply chain organized around mobile chipping machines.[29] If farmers or farmer organizations cannot find an investor or invest in a machine or pellet factory themselves, farmers can sell cotton stalks as raw material for wood-based industries.

Few farmers know what to do to add value to the stalks, so there is a need to raise awareness, build capacity and share knowledge with then on the full potential of cotton stalks. Farmers can be taught to explore opportunities for farm-level value addition either individually or (preferably) collectively, with village groups or cooperatives.

Farmers also must be able to finance their own production. Value-added activities for cotton stalks probably won't develop without deliberate policy incentives to encourage investment in or adoption of technologies to add value.

The top challenge in operating a briquetting or pelleting factory is to ensure a reliable, inexpensive supply of suitable agricultural residues from nearby areas. Other challenges include reliable power supply, availability of skilled labour and access to end users.

Logistics for cotton stalk collection is a key success factor. The supply model developed in India involves the following steps:

- uproot cotton stalks;
- dry by sun in the field for 7–10 days;
- aggregate the stalks in a central location, no further than 5 kilometers from where they were grown;
- chip using a tractor-operated chipper.[30]

It is also important to provide proper storage conditions for chipped stalks.[31]

[29] A briquetting plant of four tons a day requires about 1,000 tons of biomass a year, equivalent to 300–400 hectares on average, or a catchment radius of 25–30 kilometers, according to the United Nations Conference on Trade and Development.

[30] Up to 1.3 tons of stalks can be obtained from one hectare under rain-fed conditions.

[31] Unchipped stalks stored in the open are more susceptible to degradation by insects, whereas chipped stalks stored in shaded or covered conditions suffer no insect damage and preserve their chemical and quality characteristics.

Chapter 4
Recommendations

Oil cake as animal fodder (© Shutterstock)

There is a growing market for cotton by-products in Africa, and they could become an important complementary source of revenue for the cotton sector. Yet they have received little attention to date. This means the potential of cotton by-products is far from fully exploited and their markets are not well developed in sub-Saharan Africa.

Enormous untapped potential

Cottonseed is a source of many useful products, from oil and hulls to cake and linters. While most cotton-producing countries in Africa have industries to process cottonseed into edible oil and livestock feed, technologies to add value to other by-products are underused across the continent. This means there is considerable scope for value addition to these goods.

Successfully developing cotton by-products will depend on the following factors:

- cost of raw material in a usable form, delivered to the processing industry gate;
- development of supply chain logistics for collection, preparation, storage and transportation from field to industry;
- production costs;
- affordability and simplicity of the processing technology;
- level of capital investment;
- existence of a market for the by-products;
- cost and quality competiveness.

The way forward

The following steps are necessary to develop cotton by-product value chains in sub-Saharan Africa:

- Identify and assess value-addition activities (processing and marketing of cotton by-products) in the national context. This includes evaluating the economic performance of different types of oil processing (small-scale, labour-intensive and traditional versus large, capital-intensive and technologically efficient), including the indirect benefits for the national economy in terms of job creation and value added.

- Raise awareness among private and public stakeholders (farmers, ginners, crushers and government officials) about the potential of cotton by-products for value addition:

  – Build awareness among farmers and farmer associations about the potential of cotton stalks to create additional income;

  – Build awareness among entrepreneurs, nongovernmental organizations, financial institutions, government agencies and other stakeholders about uses of cotton stalks as a raw material for producing briquettes, pellets, compost and edible mushrooms.

- Increase transparency in the cotton sector:

  – Collect and disseminate market information on prices, production, imports and exports of products of the oilseed complex and cotton by-products;

  – Build the capacity of farmer associations to negotiate the price of seed cotton, including the true value of cottonseeds.

    The first step is raising farmer awareness and increasing transparency about the contribution of cottonseeds in the total revenue of ginners. Producers and ginners in Eastern and Southern Africa (like in franc zone countries) would benefit from setting a minimum producer price for seed cotton, taking into account the contribution of cottonseeds before planting. This would reduce producer price volatility and fluctuations in production. However, such a pricing system is only possible within a framework of strict contract farming agreements.

  – Consider using an objective formula to calculate the price of cottonseed.[32]

- Promote value addition to cotton by-products with financial and technical assistance from governments or donors:

  – Establish contact with manufacturers of processing equipment;

  – Set up a pilot demonstration plant operating cotton by-product processing technologies;

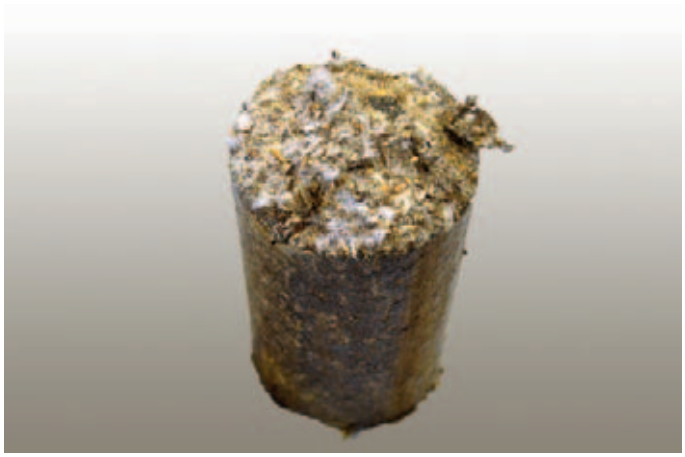
  – Establish supply chain centres in clusters of cotton growing areas for the collection, chipping and supply of cotton stalks from field to factory;

  – Study new varieties focused on oil and meal content of cottonseed (without compromising the quantity and quality of lint) and the reduction of the gossypol content in seeds.

[32] Such as the cottonseed value calculator recommended by Cotton Inc. Because cottonseed contains energy, protein and fibre, the substitution value of whole cottonseeds is equal to 0.9 x price of corn + 0.25 x price of soybean meal + 0.5 x price of hay.

Cotton plant with cotton balls (© Shutterstock / EGxperience)

Cotton stalk bales (© C.F. Nielsen A/S)



Cotton thrash (© C.F. Nielsen A/S)

Cotton briquettes (© C.F. Nielsen A/S)

- Ensure government support for the establishment of cotton by-product processing businesses:
  - Include by-products in national cotton sector development strategies, with action plans aiming to increase value addition to cotton;
  - Implement clear national policy guidance on the development of both the edible oil and meal production industry with a favourable tax regime;
  - Put in place policy incentives to encourage investment (local and/or foreign direct investment) in or adoption of technologies to add value to cotton by-products;
  - Enforce tariffs and taxes on imported oils and meals.
- Build capacity to establish well-organized industry groups (farmer associations/cooperatives, ginner associations, oilseed processor association, interprofessions, cotton boards):
  - Share knowledge and experiences related to cotton by-products;
  - Ensure effective linkage between cotton, oilseeds and livestock sectors.

- Promote South-South cooperation:
  - Value-added technologies developed in other cotton-producing developing countries – by the Central Institute for Research on Cotton Technology in India, for instance – are often well suited to the African context. They have the potential to empower African cotton farmers and entrepreneurs to benefit economically from using cotton by-products.
  - Sub-Saharan African countries can also learn from the experiences of Egypt in developing uses of cotton stalks as organic fertilizer (compost), animal feed, wood, cellulose derivatives and charcoal.
  - In Turkey, cooperative unions own and operate oil mills, which could provide important insights to African farmers to add value to their cotton. Other countries, including Brazil, China and Pakistan, provide South-South cooperation support to African countries that could also target cotton by-products.

Appendix
Cotton by-product uses

The following section presents an overview of cotton by-products and their uses.

Cottonseed

Cotton is mainly cultivated for its fibre and is often considered synonymous with cotton lint, a raw material for cotton textiles.

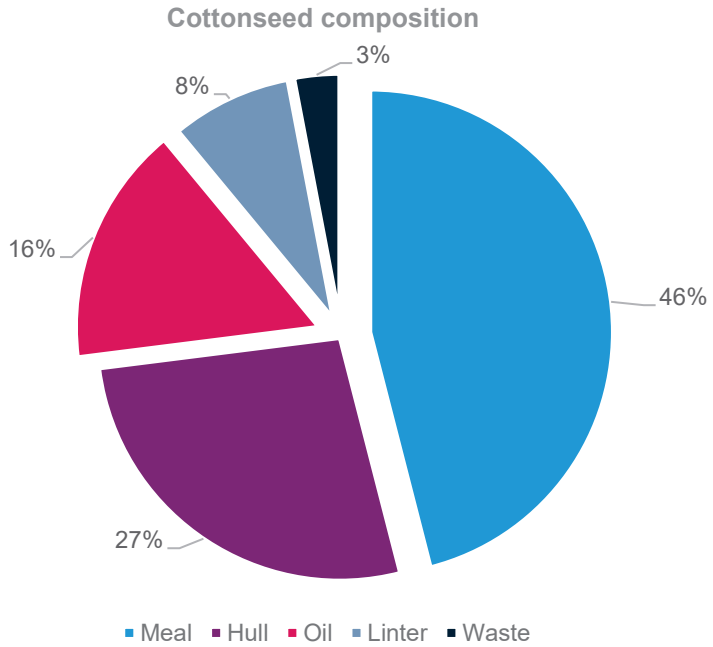
Cotton is a soft, fluffy staple fibre that grows in a boll around the seeds of cotton plants. The cotton plant is much more than just a source of lint. The ginning process of seed cotton separates the cotton lint from the seeds. Cottonseed constitute more than half of the weight of the harvested seed cotton.[33]

Until the late nineteenth century, there was no use for cottonseed, which was burned or thrown away. Today, there are many uses for the by-products derived from the non-lint parts of the cotton plant.

As cottonseed is an oilseed, cotton is both a fibre crop and a food crop. The variety of cottonseed-based by-products means cottonseed should be considered a coproduct,[34] rather than just a by-product of cotton lint.

According to ICAC's 'Cotton Facts', ginned cottonseed is generally composed of about 46% meal, 27% hull, 16% oil, 8% linter and 3% waste. Cottonseed is used for planting seeds or feeding cattle, or it is further processed to produce hulls, oil, meal, and linters in case cottonseed is mechanically delinted.

Figure 14 Meal constitutes almost half of ginned cottonseed



Source: ICAC.

[33] Depending on the cotton variety, and to a lesser extent on the technology, the ginning outturn (lint ratio) ranges from 30%–45% of the weight of seed cotton.

[34] A coproduct is produced along with and carries equal importance as a main product. A by-product is a secondary product, derived from the production process aiming at a main product.

The issue of gossypol

Gossypol is a yellow polyphenolic 'poisonous' pigment produced in the glands of whole cottonseeds and all other parts of the cotton plant. This toxin[35] is a natural pest repellent that protects the plant from insect damage. Gossypol-free (glandless) varieties have been developed in many countries, but they are less resistant to insects.[36]

Gossypol is toxic to monogastric nonruminants such as poultry and pigs, which that are unable to metabolize it like ruminants.[37]

Historically, cottonseed has not been a viable source of protein for humans due to gossypol. However, bioengineering research conducted at Texas A&M University has successfully silenced the gene responsible for gossypol production in the cottonseed.[38] Regulatory approvals will take time, but the potential for ultra-low gossypol cottonseed as a human protein source is huge.

Cottonseeds contain about 0.7%–1.5% free gossypol and 2%–4% bound gossypol. Crude oil contains around 0.6% gossypol with solvent extraction, 0.14% of the expander-solvent method and about 0.06% if the extraction process involves mechanical pressure and heat treatment.

Refining the oil removes gossypol almost completely, so refined cottonseed oil contains undetectable levels of the pigment. A very minute amount of gossypol is actually preferred in the refined oil, as it helps in the keeping quality in extended storage because gossypol is a strong antioxidant. These trace amounts were found to have no toxic effects in humans.

Cottonseed meal contains 0.08%–0.12% free gossypol and 1%–1.5% bound gossypol. Gossypol is partially removed from cottonseed meal by extraction with aqueous acetone solvent or with phosphoric acid in acetone (heated and refluxed), liquid cyclone process, ferrous sulphate treatment, calcium hydroxide treatment and solid-state microbial fermentation. These processes have the potential to reduce free gossypol by up to 80% (example: fermentation) and even up to 95% with a combination of methods.

Free gossypol is toxic, but bound gossypol is not. The maximum permissible content of free gossypol in complete feed is 0.05% (500 ppm) for cattle, 0.03% (300 ppm) for sheep and goats, 0.01% (100 ppm) for poultry and calves, and 0.006% (60 ppm) for lambs, pigs and kids.[39]

Fuzzy seeds

The primary use of cottonseeds is for plantings. Cotton is cultivated as an annual crop; each season, 3%–10%[40] of the fuzzy seeds produced are used as planting seeds for the subsequent crop.

The use of delinted seed is highly recommended to facilitate planting operations and improve the germination rate. Yet many developing countries still plant undelinted fuzzy seeds.[41]

---

[35] During the U.S. slavery period, cotton root bark was used in folk remedies to induce a miscarriage. Gossypol appears to inhibit the development of sperm or even restrict the mobility of sperm and is thought to interfere with the menstrual cycle by restricting the release of certain hormones.In a recent study, researchers found that gossypol supports the chemotherapy in patients suffering from cancers. It may block certain proteins that create resistance to chemical treatments and may also limit tumor growth.

[36] A glandless variety (GL7) was planted on a large scale for a few seasons during the 1990s in Côte d'Ivoire because of its very high ginning outturn (45%+), but had to be discontinued due to pest infestations.

[37] The saliva of ruminants contains a complex of enzymes that can detoxify gossypol.

[38] The new variety contains gossypol only in the stem, flowers and leaves, keeping only ultra-low (and digestible) levels of the pigment in the seed.

[39] Keshav Kranthi, ICAC.

[40] The share used for plantings depends on the variety, the sowing method, the plant density and the seed cotton yield.

[41] The seed rate per hectare is higher for fuzzy seeds. Fuzzy cottonseed can be planted manually, but it is unsuitable for mechanized agriculture. Fuzzy cottonseed needs to be delinted (i.e. linters must be removed from seed) to facilitate grading ad cleaning, allow for more uniform application of seed treatment, and for the seed to flow through the planter and be properly handled by the seed metering mechanism.

Fuzzy seed, or whole cottonseed, is a suitable and valuable feedstuff for beef cattle, especially dairy cows,[42] with relatively high concentrations of protein, energy and fibre.[43]

Whole cottonseed can be fed without processing or may be pelleted before feeding, which is more expensive but easier to handle.

Gossypol,[44] high fat content and the potential for aflatoxin are limiting factors of intake.

Linters

Linters are the residual short fibres that adhere to the fuzzy seed after ginning.[45] These fibres are typically less than 1/8-inch (3.2 mm) long and unsuitable for spinning.

The process of removing fuzz from seed is called delinting. Two methods are used for delinting cottonseed: mechanical and acid.[46]

Mechanical delinting occurs as the fuzzy seed is scrubbed by brushes through the interior of a perforated screen cylinder. The mechanical process leaves 1%–2% residual linters and it may damage the seed.[47] Mechanically delinted cottonseed tends to have a slightly slower germination rate compared to acid-delinted seed, but brush-delinted seeds have an extended shelf life. Mechanical brush delinting requires more energy than acid delinting and is not as thorough.[48]

Mechanical delinting is a more cost-effective and environmentally friendly way to delint cottonseed, as it can produce useable low-grade lint as a by-product and does not use any chemicals. Recovery of linters from cottonseed[49] ranges from 5%–10% of the seed weight.

Acid delinting removes all linters and is primarily used for producing quality seeds for mechanized planting. The use of acid for delinting planting seed reduces microbial contamination and controls various diseases.

Sulphuric is the most common wet acid used, while hydrochloric is the most common acid gas.

Acid delinting is the most widely used method and is efficient in removing linters. However, it is a relatively expensive process that reduces the shelf life of the planting seed and destroys the value of the linters. The use of an acid raises regulatory (environmental and safety) and maintenance issues (corrosiveness) and is not desirable if the seed is to be used as a source of protein for humans.[50]

Dilute acid delinting is the most efficient method used to remove residual lint from cotton planting seed.[51] Hydrochloric acid delinting is a more primitive method used to remove residual lint from cotton planting seed.[52]

---

[42] Cottonseed contains galactose, contributing to lactation.

[43] Whole cottonseed contains 85%–90% of total digestible nutrients, 15%–23% crude protein, 15%–20% fat and 20%–25% cellulose (linters) on a dry matter basis.

[44] Although whole cottonseed has higher amounts of gossypol than cottonseed meal, the gossypol in cottonseed meal is more readily available.

[45] After ginning, the seeds of the most commonly cultivated species in the world, Gossypium hirsutum (so-called upland cotton), are usually covered with short hairs called fuzz.

[46] Flame operations have also been used or to make delinted ('naked' or 'black') seeds for planting.

[47] Crushing the seedcoat due to the abrasive action of the brushes or reducing germination due to mechanical heat.

[48] Brush technology is improving through a variety of new brushes that offer effective mechanical delinting with lower heat generation.

[49] Linters are known as first cut, second cut or third cut (mill cut or defibrated) linters, depending on the number of fuzz removals.

[50] Mechanical means should be used for delinting low-gossypol or gossypol-free seed as a potential protein source for humans.

[51] A precisely controlled amount of specially formulated sulphuric acid mix solution is applied to the fuzzy seed in a stainless steel reactor, which reduces noxious residues and enhances production of black seed.

[52] Fuzzy cottonseed is first dried and warmed in a continuous drier and then conveyed into a preheated and rotating delinting drum where vaporized and pressurized hydrochloric gas is injected. The hydrochloric gas reacts with the lint and weakens the fibre. Cottonseed is transferred to buffing drums, where lint is removed through a mechanical scrubbing action that separates the weakened fibres from the hard seed coat. Delinted seed is neutralized with ammonia before conditioning and treating.

Every ton of cottonseed can generate around 75 kilograms of linters. In the United States, linters cost roughly 50 cents per kilogram.

Linters are about 75%–80% cellulose. They have many uses as stuffing material[53] and for the manufacture of low-grade yarns,[54] pharmaceuticals,[55] paper products[56] and chemicals.[57] Linters with longer fibres are often used for medical supplies, while those with shorter fibres are used in items ranging from gunpowder[58] to cotton balls and even X-ray film.[59]

[53] For pads, cushions, comforters, mattresses, upholstery and automobiles.

[54] For carpets, twine, rope and candles.

[55] Absorbent cotton for surgical dressings, bandages, cotton balls and cotton swabs.

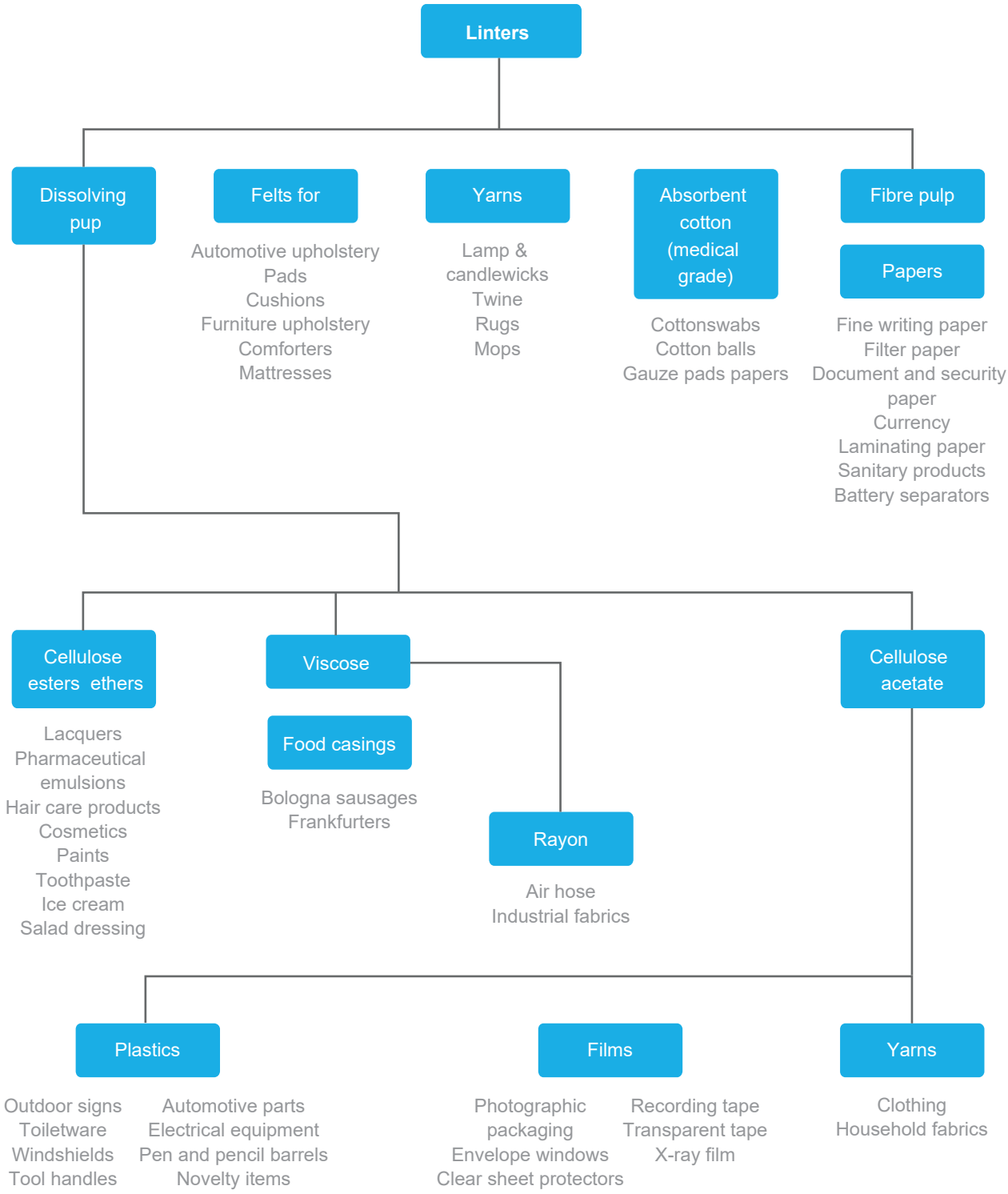
[56] Including high-grade bond paper, bank notes and filter paper.

[57] Rayon, acetate, cellophane, photographic film, explosives, etc.

[58] During World War II and the Korean War, almost all U.S. production of linters was used to manufacture smokeless powder for artillery shells.

[59] Cotton linters are used as part of the construction process for flat-screen TVs.

Figure 15 Linters have a range of uses



Source: ICAC.

Absorbent cotton

Cotton is very efficient at absorbing water.[60] However, the outer wall[61] of the cotton fibre somewhat restricts its capacity to soak up water.

Absorbent cotton[62] has medical, cosmetic, dental and many other practical uses.

The first step in the production process of absorbent cotton is the removal of the external protective layer from the fibre.[63] Linters and short staple[64] cotton can be used as raw material to produce absorbent cotton. The production process requires a considerable quantity of water and there is need for an appropriate effluent treatment plant as per environmental regulations.

End products, such as cotton balls, cotton pads and cotton swabs, must meet certain health standards.

Despite their name, most modern cotton balls and pads (outside of specifically labelled '100% Cotton' organic brands) are not made out of cotton but of cheaper, synthetic fibres such as polyester and nylon.[65]

Hulls

Hulls are the outer covering (seedcoat) of the cottonseed. They are a direct by-product of the dehulling process to expose the kernel. Recovery of hulls from cottonseed ranges from 20%–30% of the seed weight.[66]

The main uses of hulls are in the livestock feed,[67] fertilizer and soil conditioner industries,[68] as oil-well packing material, in furfural production[69] and as a raw material for various chemical industries.[70]

[60] Cotton an absorb up to 27 times its weight in water, according to Cotton Inc., as cellulose, which constitutes about 90% of the dry weight of fibre, is 'hydrophilic'.

[61] The outer wall consists of oil, wax and other cuticle layer.

[62] Absorbent cotton is also known as ''cotton wool'' or ''surgical cotton''.

[63] The process involves mechanical opening of the cotton, followed by chemical scouring and bleaching. The cotton is then washed to remove the chemicals and dried. Once dry, the cotton goes through the following processing steps: fibre opening, lap formation, carding, rolling and packaging.

[64] Any cotton with staple length shorter than 22 millemetre and micronaire above 5 micrograms per inch can be used to produce absorbent cotton. Comber noil (a by-product of the spinning industry) and cotton with lower micronaire can also be used.

[65] In the United States, these products can be labelled as 'cotton balls' because non-woven products are excluded from the Federal Trade Commission's more stringent labelling requirements for textile products.

[66] The seed hull contains 35%–60% alpha cellulose, 19%–27% pentosans, 15%–20% lignin and 5% ash, proteins, fat, etc.

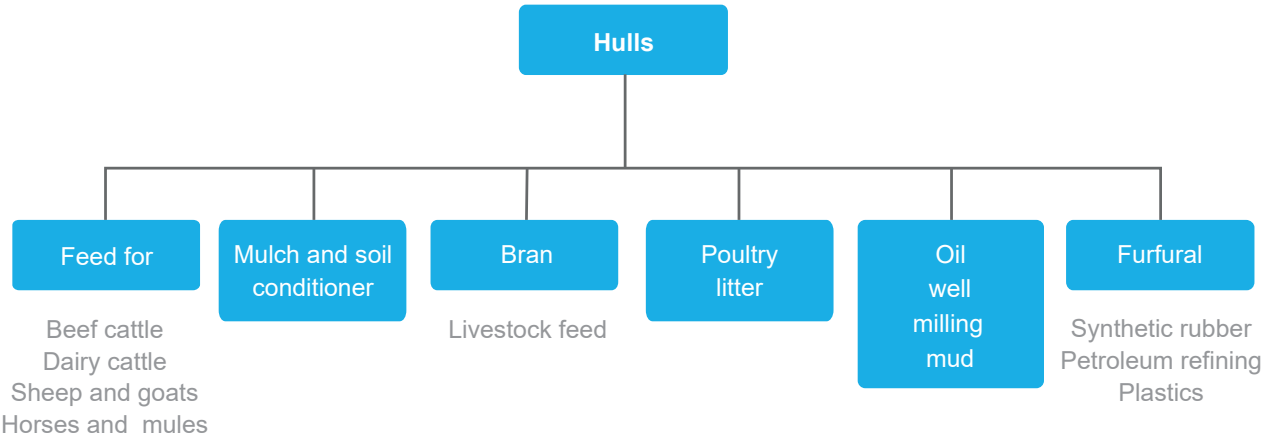
[67] Hulls are often mixed with cottonseed cake for producing compound cattle feed with higher density and lower protein content.

[68] Hulls are useful in restoring potash and minerals in depleted soils (mulch/compost).

[69] Furfural is a liquid made from the hulls used in the plastics industry; the remaining mash is used for livestock feed.

[70] Hulls are very rich in cellulose.

Figure 16 Hulls used as livestock feed and fertilizer



***Source*:** ICAC.

Cottonseed oil

In most cultivated varieties, the oil content of the whole seed ranges from 5%–22% of fuzzy seed. The kernel has an oil content of 28–35%.[71]

The cottonseed's most valuable by-product is oil, which is obtained by crushing the cottonseed kernel. Oil can be extracted either mechanically (expeller-pressing) or chemically by adding solvents

The traditional mechanical method uses a circular mortar, or a more advanced technology, such as a hydraulic press or a screw press (expeller). The cottonseeds may be dehulled,[72] cracked, dried or heated before being fed to the press. Cottonseeds are pressed, squeezed and crushed under high pressure to extract oil. The resulting cake is dried, ground and then processed into large pellets.

In the direct solvent-extraction process, the oil is extracted by solvent (usually hexane[73]) alone. The resulting cake is heated to eliminate the solvent and then typically ground into meal.

The prepress solvent-extraction process combines mechanical and chemical methods. In a first step, the dehulled, cracked, dried, heated or flaked cottonseeds are screw-pressed or expanded, and the pressed flakes or pellets are then solvent-extracted.

The expeller-pressing method is relatively simple and not capital intensive.[74] The expeller-pressing method retains most of the natural qualities (colours, flavours and nutritional qualities) of cottonseed oil, which is free of solvent or chemical residues. However, even the most powerful presses cannot remove more than 70%–80% of the oil from the cottonseed, and the level of residual oil in cakes cannot be reduced below 3%–5%.

The solvent-extraction method is far more efficient, as it can recover up to 97%–99% of the cottonseed oil. However, this technology is only suitable for large processing capacities because it is more sophisticated and more capital intensive. Eliminating the remaining traces of chemical solvents tends to affect the natural qualities of the oil.

[71] There is a negative correlation between oil and protein levels.

[72] Traditional oil-expeller technologies crush the entire fuzzy cottonseed, recovering oil and meal. In the expeller process, valuable by-products, such as linters and hulls, are wasted, and the quality of oil and meal is also poor.

[73] The use of hexane, the most widely used solvent, is criticized due to concerns about environment, health and safety. Ethanol has valuable solvent properties.

[74] Expellers are available within a large range of processing capacities.

Crude cottonseed oil is refined to make it more edible. The process of oil refining involves hydration, neutralizing, degossypolization, bleaching and deodorization to remove impurities. A semi-solid residue from the refining process called soap stock provides fatty acids for various industrial uses.[75]

Cottonseed oil is used as a cooking oil.[76] Refined cottonseed oil is used for cooking and salad dressing and as ingredient in a variety of prepared foods,[77] as well as cosmetics, nitroglycerine, composition roofing and other products.

Box 1 What are the characteristics of cottonseed oil?

Cottonseed oil is a neutral-flavoured cooking oil. In fact, cottonseed oil is the reference standard mostly used in tests evaluating the taste and the odour of other edible oils. The oil has a non-oily consistency, is shelf-stable and has a high smoking point of 220°C to 230°C.

Cottonseed oil has one of the healthiest nutritional profiles among vegetable oils. Like other vegetable oils, it does not contain cholesterol in its natural unhydrogenated state. However, it does contain more than 50% Omega-6 fatty acids and trace amounts of Omega-3 fatty acids. It also contains about 1% sterculic acids and malvalic acids in its crude form, in addition to linoleic (49%–58%), palmitic (22%–26%), oleic (15%–20%), arachidic/behenic and lignoceric (10%) acids. It contains around 9 kcal/gram, with an average digestibility of about 98%. Cotton oil has low levels of saturated fats, 70% mono- or polyunsaturated fatty acids and no trans-fatty acids. It is cholesterol-free and rich in vitamins.

Including cottonseed oil in a diet can help prevent malnutrition.

The quality of cottonseed oil reflects the degree of processing.

Cottonseed oil is naturally darker in colour than most other edible oils, but light colour can be obtained by refining and bleaching techniques.

Refined cottonseed oil (deodorized, neutralized, cleaned, bleached, with low gossypol content) has a 'mild and nutty' flavour.

Source: USDA, ICAC.

Cottonseed oil can also be used as biofuel, as an alternative to diesel. It is directly usable pure or mixed with fuel in certain diesel engines.[78] However, as direct fuel-injection engines do not accept natural vegetable oils, cottonseed oil must undergo etherification to be transformed into biodiesel.

[75] Such as insulation materials, soaps, linoleum, oilcloth and waterproofing materials, and as a paint base.

[76] Deep frying (fish, doughnuts, croquettes), pastry.

[77] Shortening, mayonnaise, margarine, cereals, breads, snacks, etc.

[78] Ranging in power from 5 kilowatts to 100 kilowatts.

Cottonseed cake/meal[79]

After the oil is extracted from the seeds, the solid residues of crushing are the cottonseed cake and cottonseed meal,[80] which are joint products or coproducts of the oil extraction process.

Cottonseed meal has a high protein content and can be used to feed livestock, particularly dairy and beef cattle, goats and sheep, as well as natural fertilizer for lawns, gardens and flowerbeds.

Cottonseed meal is mostly used to feed adult ruminants, which are relatively tolerant to gossypol, and generally unsuitable for nonruminants, such as poultry and pigs.[81] The chemical composition and nutritional value of cottonseed meals are highly variable depending on the seeds and the oil manufacturing processes used. Meals can be available as cakes, flakes or pellets.

With a protein content of about 40%, cottonseed meal contains less protein and energy than peanut meal or soybean meal.[82]

Meals obtained from undecorticated or partially dehulled cottonseeds meals are rich in fibre (more than 20%). Mechanically extracted cottonseed cakes and meals are richer in oil.[83]

Due to the presence of gossypol in the cottonseed meals generated by the expeller-pressed technology, cottonseed meals cannot be used without restrictions in all feed or food products.[84] Solvents used in modern mills using expander technology reduce the free gossypol in cake and meal.

Microbial fermentation is an effective method for degossypolization of cottonseed meal because gossypol biodegrades during the solid-state fermentation process.[85]

[79] Although both terms are generally used as synonyms, they correspond to different products. Cottonseed cakes (not ground; high residual oil); resulting from crushing whole seeds, have a protein content of about 40% of the total nutrient content and a fat content of 5%–7%. Cottonseed meal (ground, dried and pulverized cottonseed cake; low residual oil) resulting from crushing kernels have a higher protein content of about 50%, and fat content of 1%–2%.

[80] Cottonseed meal (ground, dried and pulverized cottonseed cake; low residual oil) resulting from crushing kernels has a higher protein content of about 50%.

[81] Glandless cottonseed meal is virtually free of gossypol.

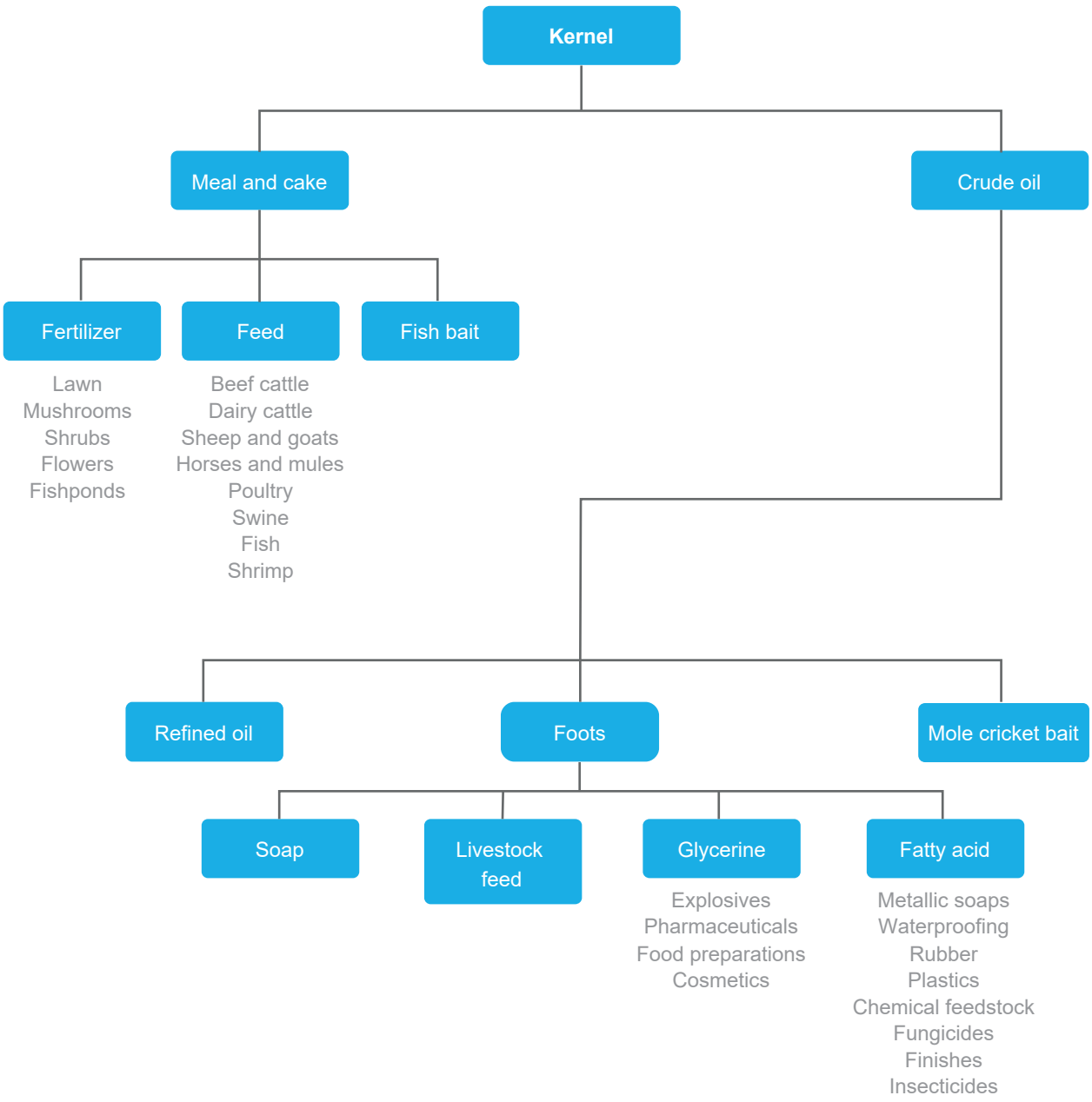
[82] Standard soybean meal contains 44% protein.

[83] Cake issued from the expeller-pressed method is often subject to further oil extraction.

[84] During processing, some of the glands are ruptured and the gossypol released. It may become bound with various compounds of the seed. The remaining gossypol, called free gossypol, is harmful when fed at high levels; the bound gossypol is less harmful.

[85] The fermented meal has reduced bound and free gossypol levels and is enriched with enzymes, vitamins and other active substances.

Figure 17 Kernel is used to produce cake and meal, crude oil



***Source*:** ICAC.

Cotton gin waste

The ginning process results in a cotton by-product known as motes, which are small, broken or immature seeds with attached fibres.[86]

The volume of such waste is substantial, especially with machine-picked cottons.[87]

Most the waste (or trash) generated by the gins was traditionally discarded back to the fields at a cost, becoming a soil additive. However, motes (semi-processed or eventually reginned) can be used to produce some of the same nonwoven products that are produced using linters. Cotton waste can also be used as a source of roughage to feed the livestock, for making gardening compost, making bedding for dairy cattle and as soil amendment.

Cotton stalks

Apart from cottonseeds, which are a de facto coproduct of the ginning process, stalks are the only by-product of cotton cultivation.

Cotton cultivation generates an estimated two to three tons of stalks per hectare. In most countries, cotton stalks are burned.[88] In those where cotton cultivation is mechanized, farmers destroy stalks at the end of each season by cutting them at ground level and then shredding and incorporating them into the soil.

Agricultural residues can be:

- processed into a high-energy roughage for ruminant livestock;
- made into a fuel source for residential and industrial applications;
- made into products for erosion control and grass seed establishment;
- used as raw materials for various composite materials.

The fibrous structure of cotton stalks is comparable to that of most species of hard wood.[89] Therefore, the stalks can be used as a source of fuel, or as an alternative raw material for the manufacture of particle boards,[90] the preparation of pulp and paper, hard boards, corrugated boards and boxes, microcrystalline cellulose and cellulose derivatives, and as a substrate for growing edible mushrooms.

Biomass briquetting and pelleting technologies have been in operation for more than 20 years.

Briquetting is a simple process[91] and the pelleting process is not very sophisticated. The power requirement, energy consumption and labour requirement for a pelleting plant depend on its production capacity.[92]

Trained workers can easily maintain and repair the factory as well as the machinery[93] used in it.

---

[86] The term gin motes refers to any gin waste usable for its fibre content. It consists primarily of lint cleaner waste, but may include motes from the gin stand (the gin separates the motes from the mature, whole seeds).

[87] Mechanical harvesting increases the need for seed cotton and lint cleaning. A typical gin in the United States produces about 180 kilograms of waste by-products for each bale (217.7 kilograms).

[88] Burning destroys the habitat on which some cotton pests and diseases survive between crops.

[89] The cotton plant stalk contain about 68% holocellulose, 45% cellulose, 26% lignin and 5% ash.

[90] Particle boards are used as door panel inserts, partitions, wall panels, marking furniture items, floor and ceiling tiles, etc.

[91] Briquettes are prepared by feeding 10–15 millimetre cotton stalk chips at 10%–12% moisture content through a briquetting press, which requires 90 horsepower of connected load and six to eight workers per shift for its operation.

[92] In the pelleting process, up to 3 millimetre milled cotton stalks with 12%–14% moisture content are fed through pelleting machines. A pelleting plant of 20 metric tons per day requires about 150 horsepower of connected load, 50–60 kilowatt hours of energy and six to eight workers per shift for its operation.

[93] There are several manufacturers of briquetting and pelleting machinery in China and India.

Pellets are used for power generation and industrial and large-scale heating purposes in many developed and developing countries. Pellets are easy to handle and burn easily in boilers because of their uniform shape, size and high energy density.

Processing cotton stalks as raw material to produce particle boards involves the following steps:

- chipping stalks;
- drying chips;
- hammering chips into finer grade;
- separation of coarser and finer grades;
- mixing with glue and spreading it out in a parallel and uniform way;
- Cold pressing followed by hot pressing to obtain boards.

Box 2 Cotton stalk-based by-products have many benefits

Benefits of pellets:

- priced one-third of commercial gas (cheaper than coal);
- renewable energy;
- pollution-free (no sulphur content);
- higher thermal value;
- lower ash content compared to coal (1%–3% vs 20%–25%);
- no ashes flying while burning;
- lower moisture than coal (2%–3% vs 20%–25%);
- produces white smoke;
- high burning efficiency;
- low transportation cost (produced locally).

Recycling cotton stalks into organic fertilizer (compost) can:

- create a potential source of revenue;
- provide employment to non-qualified persons;
- reduce use and imports of mineral fertilizers;
- prevent emission of carbon dioxide generated by burning stalks.

Source: Author, based on inputs from ICASC, USDA and the United Nations Conference on Trade and Development.

References

Aboissa – Commodity Brokers (2018). 'Cotton by-Products: The perspective of the Brazilian Private Sector.'

Agarwal, D.K., P. Singh, M. Chakrabarty, A.J. Shaikh and S.G. Gayal (2003). *Cottonseed Oil Quality, Utilization and Processing*. Nagpu: Technical Bulletin - Central Institute for Cotton Research.

Angadjiwand, S. (2018). *U.S. Farm Commodity Support: An Overview of Selected Programs*. Congressional Research Service.

Baffes, J. (2010). 'Markets for Cotton by-Products: Global Trends and Implications for African Cotton Producers.' Policy Research Working Paper 5355. The World Bank, Washington D.C. https://doi.org/10.1596/1813-9450-5355

Bajoria, S.S. (2016). 'Effective and Practical Use of Cottonseed and Its By-Products.' Cotton Association of India. 2016. Cotton Statistics & News No. 18. 2 August 2016.

Balasubramanya, R. H. and A. J. Shaikh (2007) 'Utilisation of Cottonseed By-Products.' Central Institute for Research on Cotton Technology, Matunga, Mumbai.

Bharimalla, A.K. (2019). *Absorbent Cotton Technology*. Central Institute for Research on Cotton Technology.

Blezinger, S. (1998). 'Considerations in the Feeding of Cotton Co-Products.' Cattle Today Inc.

Buka, G. (2016). 'Cotton and Its By-Products Sector in Zimbabwe.' UNCTAD Background Paper UNCTAD/WEB/SUC/2017/3.

Common Fund for Commodities. Technical Paper Nr. 58. 2010. 'Utilization of Cotton Plant By-Products for Value Added Products.' Final Report of Project CFC/ICAC/ 20. Executed by Indian Council of Agricultural Research and Central Institute for Research on Cotton Technology.

Chigumira, G. (2017). 'Cotton and its by-products in Zimbabwe – Analysis of Cotton by-products Survey.'

Chitah, W.K. (2016). 'Cotton and Its By-Products Sector in Zambia.' UNCTAD Background Paper UNCTAD/WEB/SUC/2017/2.

Central Institute for Research on Cotton Technology. 'Utilisation of Cotton by-Products for Value Added Products.' Project Paper prepared by the Central Institute for Research on Cotton Technology, Mumbai, India.

Cotton Incorporated. https://cottontoday.cottoninc.com/cotton-byproducts/

Desrochers, P., and J. Szurmak (2017). 'Long Distance Trade, Locational Dynamics and By-Product Development: Insights from the History of the American Cottonseed Industry.'

Ely, L., and L. Guthrie (2008). *Feeding Whole Cottonseed to Dairy Cows and Replacements*. The University of Georgia College of Agricultural and Environmental Science.

Food and Agriculture Organization of the United Nations (2014) 'Crop residues and agro-industrial by-products in West Africa - Situation and way forward for livestock production.'

Holt, G., J. Simonton, M.G. Beruvides and A.M. Canto (2004). 'Utilization of cotton gin by-products for the manufacturing of fuel pellets.' *Economic perspective*.

Holt, G. (2016) 'Bioinspiration and biomimicry: Possibilities for Cotton by-products.' Paper presented to the 33rd International Cotton Conference Bremen, 16 to 18 March 2016.

_____ (2018). 'Finding Successful Applications/Products Utilizing Cotton Plant Materials.' ICAC 77th Plenary Meeting, Abidjan, Côte d'Ivoire, 2 to 6 December 2018.

International Cotton Advisory Committee (2000). 'The Cottonseed.' *International Cotton Advisory Committee Recorder, XVII*, 3–8.

_____ (2003). 'Cotton Facts.' Technical Paper No. 25 of the Common Fund for commodities.

_____ (2019). 'World Cotton Statistics.' November 2019.

_____ (2020). 'Cotton this Month.' June 2020.

International Trade Centre. 'Trade Map.' June 2020.

Kabissa, J.C.B. (2016). 'Cotton and Its By-Products in the United Republic of Tanzania.' UNCTAD Background Paper UNCTAD/WEB/SUC/2017/1.

Kelly, V., S. Perakis, B. Diallo and N.N. Dembele (2010). 'Cottonseed, oil and cake: Co-products or byproducts in the C – 4 cotton sectors?' USAID – WACIP Project Report.

Lugojja, F. (2017). 'Cotton and Its By-Products in Uganda.' UNCTAD Background Paper UNCTAD/WEB/SUC/2017/4.

Mageshwaran, V. (2019). 'Degossypolization of Cottonseed Meal: A Microbial Method to Produce some Protein Source for non-ruminants Feed.' Central Institute for Research on Cotton Technology.

Mageshwaran, V. and V. Satankar (2019). 'Technology on Oyster Mushroom Cultivation Using Cotton Stalks.' Central Institute for Research on Cotton Technology.

Neves, M.F., M.J. Alves Pinto, and Júnio de Lima (2012). 'Mapping and Quantification of the Cotton Chain in Brazil – Industry Speaks.' *The International Food and Agribusiness Management Review*, 15(4), 2012.

Nkouam, G.B., A.L.D. Tchefenjem, C. Kapseu, R.M. Nguimbou, G. Zomegni and Z. Mouloungu (2017). 'Production, analysis and uses of cotton oil in tropical Africa: A review.' *Agricultural Science Research Journal*, 7(2), pp. 42–46.

Organisation for Economic Co-operation and Development and the Food and Agriculture Organization of the United Nations (2015). 'Vegetable oil projections: consumption, per capita food use.' *Agricultural Outlook*.

Owis, A.S., W.M. El-Etr, F.S.D. Badawi, A.A.A. El-Soud and A.F.M. Abdel-Wahab (2016). 'Bio-processing of cotton stalks residues for producing high quality compost' 9, pp. 43–54.

Patil, P.G. (2015). 'Cotton by-products and its Potential Applications.' ICAR-Central Institute for Research on Cotton Technology – ICAC 74th Plenary Meeting, Mumbai, December 2015.

Roberson, R. (2009). 'Cotton gin trash now valuable by-product.' *Southeast Farm Press*. 18 March 2009.

Shaikh, A.J., R.M. Gurjar, R.H. Balasubramanya and P.V. Varataraga. 'Utilisation of Cotton Stalk in Production of Particle Boards.'

Shukla, S.K. (2019). 'Briquetting and Pelleting Technologies and Practices.' Central Institute for Research on Cotton Technology.

Standifer, M.M. 'Cottonseed Industry.' Texas State Historical Association.

Stewart, L. (2010). 'Using Cotton by-products in Beef Cattle Diets.' University of Georgia Cooperative Extension Colleges, Bulletin 1311, February 2010.

Terauds, K. (2018). 'Promoting Cotton By-Products in Eastern and Southern Africa - Commercial products from cotton stalks.' ICAC 77th Plenary Meeting, Abidjan, Côte d'Ivoire, 2 to 6 December 2018.

Tschirley, D., C. Poulton and P. Labaste, (Eds.), (2009). *Organization and Performance of Cotton Sectors in Africa: Learning from Reform Experience*. Washington D.C.; The World Bank. https://doi.org/10.1596/978-0-8213-7770-3

USDA-Foreign Agriculture Service (March 2010). 'Uzbekistan. Oilseeds and Products Annual Report.'

_____ (January 2020). 'Ethiopia Oilseeds and Products Annual Report.'

_____ (March 2020). 'Australia. Oilseeds and Products Annual Report.'

_____ (March 2020). 'China (People's Republic of). Oilseeds and Products Annual Report.'

_____ (March 2020). 'Egypt Oilseeds and Products Annual Report.'

_____ (March 2020). 'India. Oilseeds and Products Annual Report.'

_____ (March 2020). 'Turkey. Oilseeds and Products Annual Report.'

_____ (April 2020). 'Brazil. Oilseeds and Products Annual Report.'

_____ (April 2020). 'Pakistan. Oilseeds and Products Annual Report.'

_____ (April 2020). 'South Africa Oilseeds and Products Annual Report.'

_____ (June 2020). 'Oilseeds: World Markets and Trade.'

World Bank (April 2020). 'Commodity Price Outlook.'

_____ (April 2020). 'Commodity Price Forecasts.'

_____ (June 2020). 'Commodity Price Data.'

Printed by ITC Digital Printing Service.

A free pdf is available on ITC's website at:
www.intracen.org/publications.


International
Trade
Centre