OCL 2016, 23(6) D606
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DOI: 10.1051/ocl/2016043

Available online at:
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RESEARCH ARTICLE – DOSSIER

OPEN ACCESS

OIL CROPS AND SUPPLY CHAIN IN ASIA
LA FILIÈRE OLÉAGINEUSE EN ASIE

Review of the cotton market in Pakistan and its future prospects

Tassawar Hussain Malik[1,★] and Muhammad Zahir Ahsan[2]

[1] Director Research (Headquarters), Pakistan Central Cotton Committee, Multan, Punjab, Pakistan
[2] Plant Breeding Section, Central Cotton Research Institute, Sakrand, Sindh. Pakistan

Received 5 September 2016 – Accepted 13 October 2016

Abstract – Pakistan is the world's 4th largest producer of cotton. Cultivation along the Indus River extends across nearly 3 million hectares and serves as the backbone of the economy. Despite this importance, information on the cotton sector in Pakistan, in particular with regard to cotton oils, is scanty and not available from a single source. This review seeks to remedy that gap. Though cultivated mainly for fiber, its kernel seed oil is also used as an edible vegetable oil and accounts for a large share of the local oil industry; per capita consumption of edible oils is nearly 14 kg, which is much higher than consumption in countries at similar levels of economic development. Pakistan fulfills 17.7% of its demand for edible oils through cottonseed oil. Total demand for this purpose in 2029–30 is estimated at 5.36 million tons of which local production will be 1.98 million tons. Genetically modified (Bt) cotton was introduced in Pakistan in 2010 to control three deleterious lepidopterous insects; it now accounts for more than 85% of the cotton cultivated. There is good scope for organic cotton production in Pakistan, especially in non-traditional cotton growing areas where there is less insect pressure. High temperature and water scarcity associated with climate change are a major concern, since current cultivation takes place in areas that already experience extremely high temperatures.

Keywords: Pakistan cotton / cottonseed oil / cotton seed cake / cotton research

Résumé – Analyse du marché du coton au Pakistan et de ses perspectives d'avenir. Le Pakistan est le 4ème producteur mondial de coton. Les cultures s'étendent sur près de 3 millions d'hectares le long du fleuve Indus et sont l'épine dorsale de l'économie du pays. Pourtant, l'information sur le secteur du coton au Pakistan, en particulier en ce qui concerne les huiles de coton, sont rares et non disponibles à partir d'une source unique. Cet article vise à remédier à cette lacune. Cultivée principalement pour la fibre, l'huile de coton est également utilisée comme une huile végétale alimentaire et représente une part importante de l'industrie pétrolière locale ; la consommation par habitant d'huiles alimentaires avoisinne les 14 kg, ce qui s'avère beaucoup plus élevé que la consommation dans les pays de niveaux similaires de développement économique. Le Pakistan répond à 17,7 % de sa demande d'huiles alimentaires *via* l'huile de coton. La demande totale en 2029–30 est estimée à 5,36 millions de tonnes, la production locale en assurant 1,98 millions de tonnes. Génétiquement modifié (Bt) le coton a été introduit au Pakistan en 2010 pour contrôler trois lépidoptères nuisibles ; elle représente désormais plus de 85 % du coton cultivé. Il existe de réelles possibilités de production de coton biologique au Pakistan, en particulier dans les régions productrices non traditionnelles où la pression des insectes s'avère inférieure. Une température élevée et la pénurie d'eau associée aux changements climatiques représentent une préoccupation majeure, étant donné que la culture actuelle a lieu dans les zones qui enregistrent déjà des températures extrêmement élevées.

Mots clés : Pakistan / coton / huile de coton / tourteaux de coton / recherche

History and importance of cotton

Pakistan is a key player in global cotton markets (see Figs. 1 and 2). As the world's 3rd largest producer of yarn and 2nd largest exporter, the 7th largest producer of cloth and 3rd largest exporter (ICAC, USA), Pakistan's cotton and cotton products account for nearly 60% of its overseas earnings. Though the cultivation of cotton plants accounts for less than 10% of value-added in agriculture and about 2% of Pakistan's GDP, Pakistan's economy is heavily reliant on cotton and its derivatives (Bakhsh *et al.*, 2009; Sial *et al.*, 2014).

Cotton cultivation, spinning and weaving in the Indus valley date at least as far back as 3000 BCE (Hutchinson, 1954), a time when cotton was similarly used in Egypt. *Gossypium arboretum*, which evolved from the primitive *Gossypium herbaceum*, whose cultivation has been traced back to 6000 BCE in the ancient remains of Monjadharo, is the

★ Correspondence: dtmalik@gmail.com

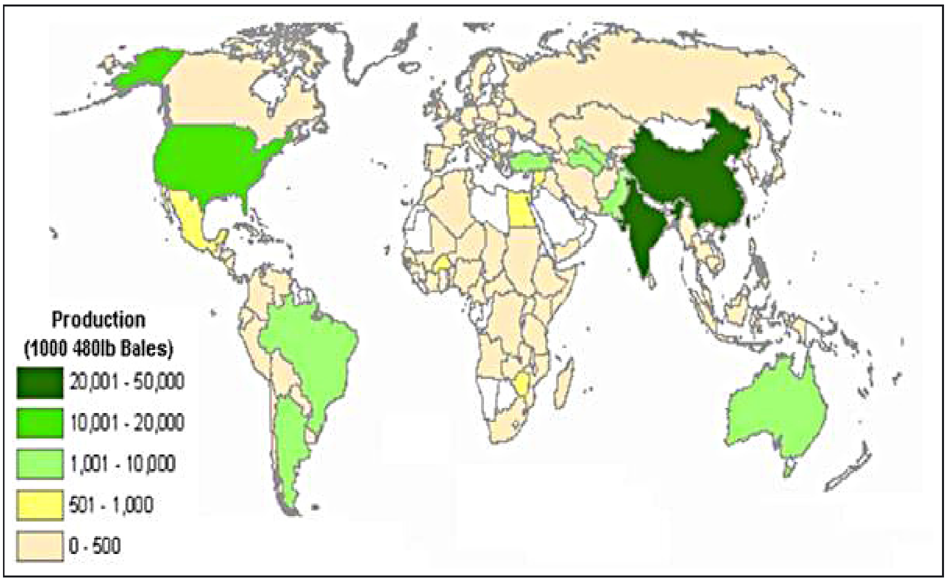

Fig. 1. Global cotton map (Source PSD Online http://www.fas.usda.gov/psdonline).

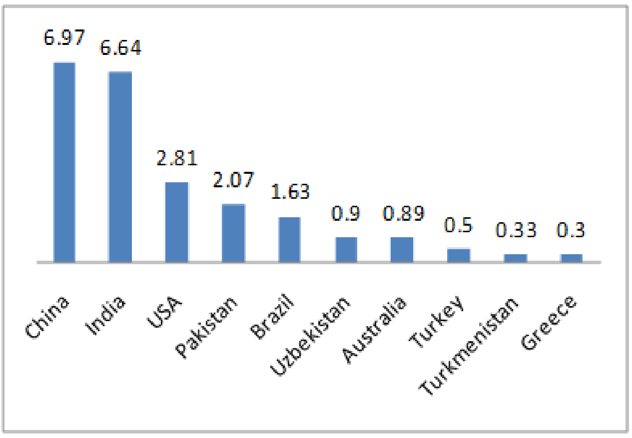

Fig. 2. World ten leading cotton producing countries (MMT) during 2013–14 (Source: Statista http://www.statista.com/statistics/263055/cottonproduction-worldwide-by-top-countries/).

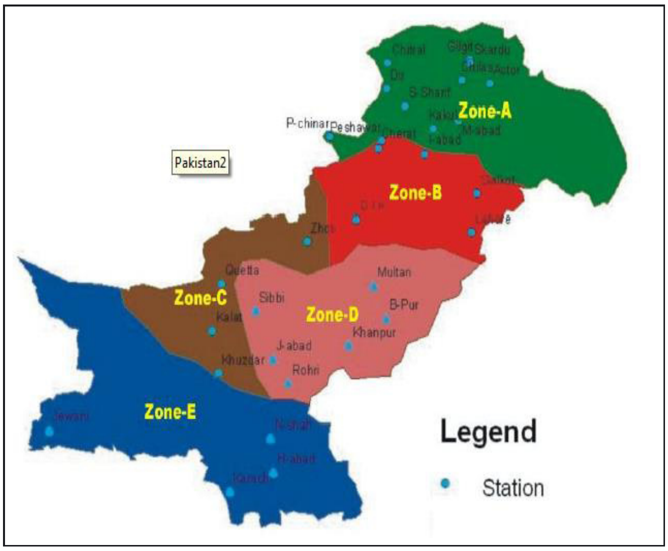

Fig. 3. Climatic zones of Pakistan (Source: Salma *et al.*, 2012).

indigenous cotton of the Indian sub-continent (Moulherat *et al.*, 2002). *G. arboreum* had six species out of which "bengalense" were cultivated in Pakistan (Rahman *et al.*, 2012). *Gossypium hirsutum* cultivation commenced in parallel to the sub-continent's textile revolution in the 1930s (Rahman *et al.*, 2008) and with the passage of time, cultivation has shifted to this species; *G. arboreum* is now planted on less than 2% of the land used for cotton in Pakistan; a continued decrease is expected.

Climate change and cotton production

Pakistan's cotton belt extends over 1200 km along the Indus River between the latitudes of 27 °N to 33 °N and altitudes from 27 m to 153 m. The soil varies from sandy to clay loam with clay dominant towards the south (Gillham *et al.*, 1995). In all, the cultivation of cotton covers 2.78 million hectares.

Cotton is cultivated mainly in two provinces: Punjab, the most important, and Sindh (Fig. 3). In Punjab it is cultivated mainly in Bahawalnagar, Bahawalpur, Rahim Yar Khan, Multan, Vehari, D.G. Khan, Khanewal, Rajanpur, Muzafargar and Lodhran Districts. In Sindh, it is mostly cultivated in Sanghar, Nawabshah, Ghotki and Nosheroferoz districts. These areas fall in Zone D. This is the hottest and dry zone of the country where the highest temperatures in the country are recorded.

Due to their vertical tap root system, cotton plants are tolerant to high temperatures and to drought. They are however sensitive to water availability, especially at the flowering and ball formation stages. Increases in temperature enhance growth and development, so long as they do not exceed 32 °C.

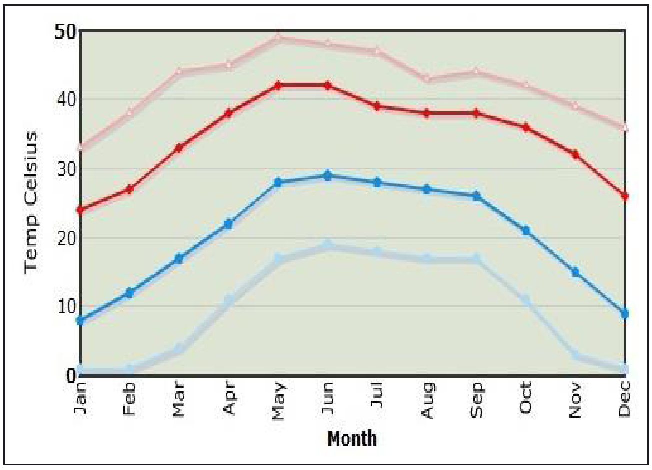

Fig. 4. Temperature of cotton region in Pakistan (Source: http://www.myweather2.com/City-Town/Pakistan/Multan/climate-profile.aspx).

Table 1. Area, production and average yield of cotton in Pakistan during 1947–2014.

Sr.	Year	Area (million hectares)	Lint production (million bales)	Av. Lint yield (kg/ha)
1	1947–48	1.24	1.11	362
1	1949–50	1.11	1.24	452
2	1959–60	1.34	1.64	494
3	1969–70	1.76	3.01	326
4	1979–80	2.08	0.73	350
5	1989–90	2.59	8.56	560
6	1999–00	2.98	11.24	641
7	2009–10	3.1	12.9	707
8	2014–15	2.78	1.48	810

Source: Economic Survey 2004-05 Statistical Appendix pp. 24–25, Economic Survey 2010-11.

Due to very limited rainfall (150 to 750 mm), cotton production is dependent on irrigation (Fig. 4). According to the WWF (2005), cotton takes the third biggest share of fresh water after rice and sugarcane. Average cotton production in Sindh is 850 kg/ha and in Punjab 692 kg/ha (Tabs. 1–3). Both these figures for irrigated cotton are low when compared with the average world yield. Among the key factors contributing towards this low yield are high temperature, lower availability of water and less mechanized farming.

Pakistan is the cotton producer most vulnerable to climate change (Asian Development Bank, 2009). Cotton cultivation depends mostly on irrigation *via* the Indus River and its tributaries; these will carry less water due to the melting of icecaps on Himalayan and Tibetan Mountains and a decrease in snowfall (Rees and Collins, 2004; IPCC, 2007; Van Raaij, 2010). If a further decrease occurs in the availability of fresh water then farmers will likely shift to less water consuming crops (Pakistan, 2003). Cotton in Pakistan is a small farmers' crop: about 86% of farms are smaller than five hectares. These are most vulnerable to the climate change because they lack the financial resources and access to information needed to adapt to climate change.

Table 2. Cultivated area, seed consumed, available seed and yield per hectare during last six years.

Year	Area (million ha)	Seed required	Seed availability	Yield (kg/ha)
2009–10	3.1	40 000	12 460 (26%)	2107
2010–11	2.7	40 000	7366 (18%)	2125
2011–12	2.8	40 000	5446 (1.4%)	2416
2012–13	2.9	40 000	4630 (1.3%)	2170
2013–14	2.8	40 000	20 684 (3%)	2319
2014–15	2.9	40 000	20 951 (22%)*	–

*Percentage of certified seed. Source: Federal Seed Certification and Registration Department (FSC&RD) 2015–16.

The optimum temperature for cotton growth is 28.5 °C but in Pakistan the temperature range (Fig. 5) during the cotton season is between 40 and 45 °C, occasionally exceeding 50 °C. Heat stress is a major constraint on enhancing the per hectare yield (Raza, 2009). A study showed that a temperature increase of 0.3 °C every decade and would have drastic effect on cotton production.

The principal factors limiting cotton production in Pakistan are cotton leaf curl virus disease (CLCuV), heat stress, limited water availability, the high price of inputs (fertilizer, seed, pesticide, insecticide, etc.), the relatively higher intensity of insect pest attacks, shortage of good quality seed, seed adulteration, cotton marketing issues and the crop insurance system.

Organic cotton

Cotton consumes more pesticide than any other crop; it is estimated that 25% of the worldwide use of insecticide and 10% of pesticide use is accounted for by cotton cultivation. Pesticides sprayed across cotton fields easily run off and pollute fresh water sources. Pesticide residues are found in foods, farm animals and even in breast milk. The WHO estimates that every year 20 000 people die in developing countries due to pesticide poisoning. These chemicals not only cause cancer in adults but also have neuro-developmental effects in children. The chemicals trapped in the threads are a source of various detrimental effects such as irritated skin, rashes, headache and dizziness (Diet, 2013).

In Pakistan, 60% of pesticides are used for cotton cultivation, see Table 4 (Kang, 2013). Furthermore, the common pesticide group used in cotton is organophosphate. These have long-term residual effects to which people living in cotton belt are particularly prone. With the introduction of genetically modified (GM) cotton, the use of pesticides fell but did not cease.

People, especially in European and American countries, are now more conscious about health, and the demand of organic cotton is increasing continually. In Pakistan, Baluchistan, Khyber Pakhtunkhwa (KPK) and some districts of Punjab have potential area to grow organic cotton because the pest pressure there is low and therefore a lower amount of pesticide is needed as compared to other cotton growing areas. The districts of Nasirabad, Jaffarabad, Khuzdar,

Table 3. Province-wise and total target of cotton sowing and quantity of seed required during 2015–16.

Pakistan		Punjab		Sindh		KPK		Baluchistan	
Area (million ha)	Quantity (million tons)	Area (million ha)	Quantity (million tons)	Area (million ha)	Quantity (million tons)	Area (million ha)	Quantity (million tons)	Area (million ha)	Quantity (million tons)
3.2	40 243	2.5	30 252	0.65	8192	0.01	125	0.04	5.84

Source: Federal Seed Certification and Registration Department (FSC&RD) 2015–16.

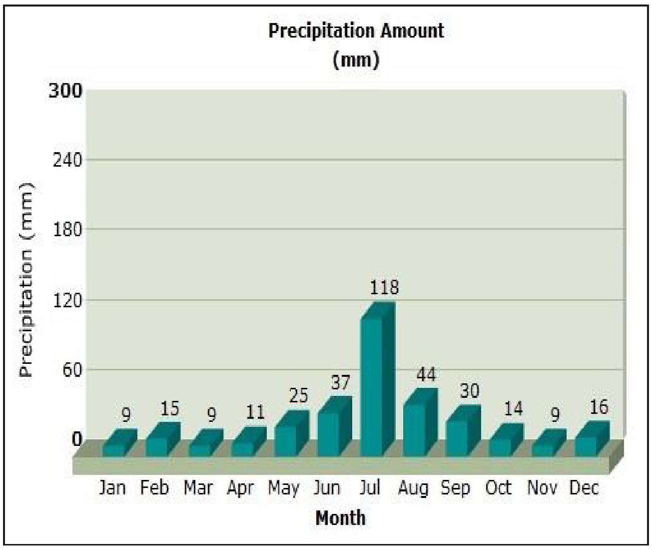

Fig. 5. Average precipitation in the cotton region of Pakistan (Source: http://www.myweather2.com/City-Town/Pakistan/Multan/climate-profile.aspx).

Table 4. Scenario of pesticide use and share of cotton.

No.	Crop	Percentage of use
1	Cotton	60
2	Rice	7
3	Sugarcane	2
4	Cereals	4
5	Others	27

Source: Kang (2013).

Kohlu and Lasbella in Baluchistan and Khan and Murdan in KPK are most suited for organic cotton production.

National agricultural research system (NARS) of cotton in Pakistan

The apex national organization with the official mandate for research and development is the Pakistan Central Cotton Committee (PCCC) of the Ministry of Textile Industry. It has three research institutes: the Central Cotton Research Institute (CCRI) in Multan, Punjab, the Central Cotton Research Institute (CCRI) in Sakrand, Sindh, and the Pakistan Institute for Cotton Research & Technology (PICR&T) in Karachi, Sindh as well as seven Cotton Research Stations in different agro-climatic locations (two in Punjab, two in Sindh, two in Baluchistan and one in KPK).

This research system oversees germplasm collection, maintenance, multiplication, characterization, distribution to public and private sector, the development of high yield and stress resistant varieties, the conduct of national coordinated varietal trials, the production of cotton publications, the provision of support to the seed production system, national and international cooperation and cotton projects management. So far through this system, more than 40 varieties have been developed via conventional breeding.

Much of the departmental activities are conducted through the Directorate of Agricultural Research of the PCCC which is the PCCC's national cotton R&D coordinating body. Three institutes of the Pakistan Atomic energy Commission (PAEC) also undertake cotton R&D activities. They include the Nuclear Institute of Agriculture and Biology (NIAB), Faisalabad; the National Institute for Biotechnology and Genetic Engineering (NIBGE), Faisalabad; and the Nuclear Institute for Agriculture (NIA), Tandojam. They have also developed different varieties through conventional breeding (mutation breeding, molecular breeding and development of transgenic).

At the provincial level, a few research stations are also developing cotton varieties. In Punjab, the Cotton Research Institute (CRI) has three research stations at Vehari, Multan and Khan. In Sindh, Balochistan and KPK, cotton botanists undertake cotton R&D activities under a slightly less coordinated provincial system.

Since the advent of GM cotton in Pakistan, various national and provincial universities as well as 10–12 registered private sector seed companies have also started a breeding and seed production program in coordination with the PCCC. Various international and national cotton R&D projects with specific objectives are also being undertaken to address a range of issues with the ultimate objective of maximizing national cotton production and quality.

Genetically modified cotton

One of the major threats to the cotton crop are attacks by chewing pests; these have been reducing annual yields by 30–40% (Masood *et al.*, 2011; Khan *et al.*, 2011). In Pakistan, unofficial cultivation of Bt. (*Bacillus thuringiensis*) cotton was started by some progressive farmers at the beginning of the 21st century. Bt. cotton was officially approved by the government in 2009 and the first crop cultivated in 2010. Prior to approval by the government agencies, illegal imports and unapproved genotype cultivation led to the distribution of substandard seeds bearing the label Bt. cotton (Ahsan and Altaf, 2009). At present more than 85% of the area under cotton is planted with Bt. cotton. From 2010 to 2014 a total of 15 Bt cotton varieties were approved for general cultivation in the country.

Table 5. By Products of Cottonseed after ginning process.

	Products	Origin	Percentage	Usage
1	Linters	Short fiber till clinging to the seed after ginning	Depends upon the species *G. hirsutum* has maximum about 10.5% but *arborium* varieties have 4.3 to 5.9%.	Cellulose products like cellulose acetate, carboxy methyl cellulose, viscose rayon, micro crystalline cellulose, cellulose nitrate, special paper, absorbent cotton
2	Hulls	A tough protective covering of the kernel	30–35% depends upon variety and species of cotton	Conventional feed rich with cellulose for cattle
3	Oil	Extracted from the kernel	20% Vegetable oil	Used as edible
4	Meal	Residue after oil extraction	40%	Rich in protein and used as animal feed

Source: Balasubramanya and Shaikh (2007).

The standard for the toxin expression of Cry1Ac gene is 1.5 µg/g (USDA/EPA) but different studies reported the average expression from 0.03 to 1.99 µg/g (Cheema *et al*., 2015) in local genotypes. Low levels of the toxin expression may lead to resistance among pests against this gene (Ferre and Van Rie, 2002). During 2014, complaints regarding the development of resistance in cotton against the target borer pests were so common as to necessitate the optimization of the gene's expression or the introduction of two or more genes to address the issues. All GM cotton-related activities are carried out under the provisions of National Bio-safety Rules and Guidelines, 2005.

To bring discipline to the national seed industry, the Seed Act of 1976 has been updated as the 2015 Seed Amendment Act; and 2016 Plant Breeders Right Bill is also being introduced in order to promote investments in local plant breeding and to strengthen national seed production programs.

Products of cottonseed

Cotton seed oil

Fiber or lint is the mail commercial product of cotton. Linters, hull, oil and meal/cotton seed cake are other products obtained from cotton-seed after ginning as mentioned in Table 5. The Chinese and Hindus extracted oil from the cottonseeds in the past through conventional methods. They used it oil in lamps and a remainder as cattle feed. However, the extraction of cottonseed oil was not developed on commercial scale. With the invention of modern technology to remove the linters and hulls, the cottonseed oil industry flourishes now across the world (Tab. 6).

And so while cotton is mainly cultivated as a fiber source its kernel is also an important source of edible vegetable oil. While soybean is the world's leading oilseed crop (282.4 million tons in 2013–14) followed by rapeseed/mustard (72.1 million tons), cottonseed amounted to 44.5 million tons (FAO, 2014).

In 1947, Pakistan was self-sufficient in oil but with the passage of time local production remained stagnant while demand grew due to an increasing population, increasing in per capita incomes and changes in consumption patterns. A study has

Table 6. World oilseed production and oil production during 2013–14.

	Oilseed	World oilseed production (million tons)	World oil production (million tons)
1	Soybean	282.4	45.11
2	Rapeseed	72.1	25.33
3	Cottonseed	44.5	5.14
4	Sunflower	41.7	14.39
5	Groundnut	38.81	4.80
6	Palm Kernal	14.6	56.63
7	Copra	5.6	–
	Total	499.7	

Source: FAO Food Outlook May (2014).

shown that if population and local production increased with the same rate, total demand would be 5.38 million tons and local production would be 1.98 million tons by 2029–30, implying the need to import 3.38 million tons. In what follows, it is assumed that population and production will grow at same rate through to 2030 (Zaman *et al*., 2010). During 2013–14, human consumption of all oils was 2.75 million tons, equivalent to a per capita consumption of 14 kg, which is twice that in the least developed countries. Major edible oils consumed by the Pakistani people are (thousand t): palm oil 1392.7 (50.63%), cotton seed oil 478.0 (17.37%), rapeseed and mustard oil 63.0 (2.29%), soybean 1.76%, sunflower seeds oil 394.7 (14.35%) and Canola oil 365.1 (13.27%).

Of the 2.75 million tons of oil consumed in total in 2013–14, 0.857 million tons (31.16%) was locally produced and the rest, *i.e.* 1.893 million tons (68.83%), was imported (Tab. 7) from different countries during the year, mostly palm and soybean oils. Of the local production, the major share (55.77%) is derived from cottonseed.

During 2013–14, cotton was cultivated on the area of 3 million hectares (Tab. 8) and produced 4.10 million tons of cottonseed with an average of 1.37 t/ha as compared to the previous year 2012–13 when total cottonseed production was 4.0 million tons at an average of 1.33 t/ha (USDA, 2014).

Cottonseed oil, classified as edible vegetable oil, is popular for cooking (stir fries, etc.) and as a salad oil (as a dressing

Table 7. Major oil imports (quantity and value) during 2009–10, 2010–11 and 2011–12.

No.	Oil crop	2009–10		2010–11		2011–12	
		Quantity (1000 t)	Value (million $)	Quantity (1000 t)	Value (million $)	Quantity (1000 t)	Value (million $)
1	Soybean	27	28	66	67	39	51
2	Palm Oil	1702	1951	2375	2021	2109	2375
3	Total	129	1979	2441	2088	2148	2426

Source: Memon (2012), Federal Bureau of Statistics.

Table 8. Cultivation, yield and production of major oil seeds in Pakistan.

No	Crop	Cultivation (million hectares)		Yield (tons per hectare)		Production (million tons)		Oil extracted (1000 T)
		2012–13	2013–14	2012–13	2013–14	2012–13	2013–14	2013–14
1	Cottonseed	3.00	3.00	1.33	1.37	4.00	4.10	478.0
2	Sunflower	0.47	0.40	1.49	1.50	0.70	0.60	251.0
3	Rapeseed	0.38	0.36	0.92	0.89	0.35	0.32	128.0
4	Others	0.11	0.11	–	–	0.10	0.10	–
5	Total	3.96	3.87	1.30	1.32	5.15	5.12	857

Source: Economic survey of Pakistan 2013–14, oilseed development board.

Table 9. Fatty acid comparison of cottonseed oil with major oil source.

Oil source	Fatty acid composition						
	Myristic 14:0	Palmitic 16:0	Stearic 18:0	Others	Oleic 18:1	Linoleic 18:2	Linolenic 18:3
Cottonseed	0.79	24.70	2.20	–	20.87	50.76	–
Sunflower	0.38	4.27	5.46	–	49.41	40.48	–
Soybean	–	10.33	3.86	–	26.52	52.92	6.37
Mustard	–	2.10	0.39	3.01	10.31	13.80	11.52
Palm	1.50	45.00	4.00	–	39.00	10.50	–

Source: Agarwal *et al*. (2003).

Table 10. Tocopherol contents in various edible oils.

No.	Oil	Total (mg/100 g)	Content (mg/100 g)			Alpha-tocopherol Equivalent
			Alpha	Beta	Gamma	
1	Canola	66	19	43	4	23
2	Corn	104	26	75	3	33
3	Cottonseed	65	35	30	–	38
4	Olive	13	12	1	–	12
5	Palm-Oil	26	6	11	9	8
6	Rapeseed	67	22	19	26	24
7	Soybean	104	10	70	24	17
8	Sunflower	65	62	3	–	62

Source: Agarwal *et al.* (2003).

or as a component in mayonnaise) that tastes like nut oil. Different varieties of cotton seeds have varying levels of different fatty acids and chemical compositions. A table spoon (13.6 g) of cottonseed oil typically contains 120 calories and 3.5 g of saturated fats. It is a good source of antioxidants, vitamin A and vitamin K. As such, it is considered to be part of a healthy and nutritious diet.

The oxidative stability of cottonseed oil is limited by its high level of linoleic acid (18:2) (Tab. 9), which increases its propensity to become rancid. To compensate for this, it is partially hydrogenated. This reduces the level of linoleic acid but increases the quantity of undesirable trans-fatty acids (Dowd *et al.*, 2010).

Cottonseed oil also has a high content of tocopherols, natural antioxidants that contribute to the prolonged shelf-life of the product. These natural antioxidants are retained at high levels in fried products and keep them fresh for longer period of time. Alpha-tocopherol is the most abundant and most active in vitamin E activity. Its concentration is higher in cottonseed oil than most other seed oils (Tab. 10).

Conclusion

In Pakistan, nearly 1.5 million people are engaged in the cotton value chain. Pakistan is 4th largest cotton lint producing country. Most of the research and development work done in the country is oriented towards the lint yield and lint quality enhancement. Along with lint production, Pakistan also meets its 17.7% of edible oil requirements through cottonseed oil. Information on cottonseed oil and its utilization is however scanty and not available in single source. There is strong demand from industry to further purify cotton seed oil to render it fit for direct consumption as cooking oil instead of hydrogenating it as ghee (solid form).

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Cite this article as: Tassawar Hussain Malik, Muhammad Zahir Ahsan. Review of the cotton market in Pakistan and its future prospects. OCL 2016, 23(6) D606.