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Textile industry can be less pollutant: introducing naturally colored cotton

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Abstract: Studies in agribusiness and textile industry, both involved with the production of manufacturing fashion presents insufficient development for new products that could represent water savings or reduction of chemical effluents, making this production chain a a sustainable business. This paper introduces the colored and organic cotton as an alternative to foster colored cotton producing farmers and improving the concept of sustainability in the textile sector. Results show that the increase in the production of colored and organic cotton may result in reduction of water use, and consequent reduction in the disposal of effluents in nature. As the colored and organic cotton is produced by small farmers, governmental agencies are required to participate in the effort of improving its production and distribution, providing the needed infrastructure to meet the increasing business. This action would slowly encourage the reduction of white cotton consumption in exchange for this naturally colored product. The water used, and consequent polluted discharge in the use of colored cotton in the textile industry might be reduced by 70%, assuming a reduction of environmental impact of 5% per year would represent expressive numbers in the next ten years.

Key words: Agribusiness Chain, Supply Chain, Sustainability in the Fashion Industry.

1. Introduction

Worldwide the production of cotton fibers reach 70 million tons per year, occupying near 10% of arable land, reaching 34 million ha. The consumption of cotton in the textile fiber chain reaches 24.6 million tons per year transforming into various garments for apparel, hospitals linen, uniforms, etc. The textile chain has a turnover of US$ 400 billion per year (Mapa, 2012). Brazil is the fourth largest producer of apparel, and it is the world's fifth largest producer, with near 30 thousand industries, which manufactures annually, near 10 billion pieces, and employing (directly and indirectly) 8 million workers, representing 16.4% of formal employment in the country. The sector revenues reached U.S. $ 60.5 billion in 2011, representing 3.5% of Brazilian total GDP, and 5.5% of the manufacturing industry in the country's GDP, a growth that exceeded 10% compared to 2010 (Abit, 2012).

Brazil has the highest productivity rates among leading cotton producer countries. As a result from the investigation for almost 20 years of Embrapa Cotton (Brazilian Enterprise in Agriculture, a governmental agency) a genetic seed of colored cotton was developed, along with special experience in its production, processing and marketing. Available in different shades of brown, the agroecological cotton does not need to be tinted, and because of that it does not impact either in peoples' health or the environment. The cotton cultivated variety was developed to minimize the use of chemical during production and processing, being a product that can be used by the organic market (Table 4, Figure 1).

According to Beltrão *et al.* (2009), this production has been developed mainly in the Northeast of Brazil, especially in the state of Paraiba and put Brazil in the global market of organic cotton. To keep the business at a fair price, however, quality and reliability of production needs to be dependable for ensuring the availability of jobs in family farming (Cartaxo *et al.*, 2008). From 2007, 265,517 bales of organic cotton were produced in 24 countries, and global production grew almost 50% per year (Ota, 2009). This paper deals with the production of agro-

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ecological and colored cotton as a real possibility of sustainable product for Brazilian agribusiness, showing the benefits in terms of water saving and effluent reduction in relation to the production of white cotton, over a period of ten years.

2. Methodology

A literature review was done on the subject of cotton and colored cotton production. Data were collected in former studies on the production of colored and organic cotton including the quantification of industries' use of water, quantity and quality of effluents, and chemicals involved in the various phases of processing (Galindo *et al.*, 2001; Sauer, 2002; Beltrão and Carvalho, 2004; Forgiarini, 2006; Beltrão *et al.*, 2009; Abit, 2012). Data on sustainability principles and social responsibility regarding family farming was also searched (Refosco *et al.,* 2011; Abreu *et al.*, 2012; Baskaran *et al.*, 2012).

This study was approved by the Ethics Committee of the Universidade Paulista. The figures obtained were subjected to a descriptive analysis to present a projection on possible savings in water use when colored cotton is used when compared to white cotton. Reduction of effluent was also accounted when considering the textile industrial processes.

3. Results and Discussion

3.1. Textile production chain chemical components output

Fashion production chain is represented by several industries such as agroindustry and the chemical industry fueling its main stream (spinning, weaving, knitting and non-woven materials (Mendes, 2010). These cotton fibers supply the clothing industry to cater to the customer for different types of retail, and this value chain is highly polluting and aggressive by nature excessive water consumption (Table 3), as well as by dumping effluents in nature (Table 1).

Studying ten cotton processing textile industries, Martins (1997) identified the reject the industry produces. These processes occur at all stages of the textile industry (manufacturing synthetic fibers and natural, spinning, weaving and knitting, pretreatment of fabrics, dyeing, printing, finishing, manufacturing, retail) (Forgiarini, 2006).

The use of water in the processing phases for producing 1 ton of knitting is also very high. Table 2 shows that the reduction on the use of water is approximately 70% for processing the colored and ecologic cotton, as indicated by Baskaran *et al.* (2012).

Table 1. Dejects generated in the production process (source: Adapted from Beltrão *et al*. (2004); Galindo *et al.* (2001) and Martins (1997)).

Phase	Components of the dejects
Pre-ironing	Humectants, salts, caustic soda, and peroxide
Ironing	Starch and synthetic gums based on poly-acrylate
Bleaching	Humectants, salts, caustic soda, sequestrates, peroxide and / or chlorine and neutralizers
Dyeing	Colorants, sequestrates, salts, caustic soda and / or kelp
Stamping	Dyes, caustic soda and gums
Washing	Detergents
Softening	Softeners and sliding

The study of the chemical processes involved in the textile industry uses large amounts of water, and the environment around it becomes contaminated by chemicals and dyes after the industrial process. The waste in all its states (solid, liquid and gaseous), and the operations of bleaching dyeing and finishing effluents emit various chemical, which can cause problems for people and the environment when improperly discarded. The processing of cotton yarn is also to various processes for transforming raw materials of the textile articles in a natural state white, dyed, printed and finished as well as downsizing, produce polluting effluents. In the complexity surrounding the textile chain, there are still wet finishing processes in which prepares the fabric to be dyed, print by color or design or receive finishing. Substances such as water, resins, dyes and surfactants are used in this phase of the process (Forgiarini, 2006).

The main chemical products and dyes found in textile effluent are from various origins (Martins, 1997), and the author highlights the most polluting

Table 2. Basic water consumption for producing 1 ton of processed 1 ton of white cotton (source: the authors).

Water consumption for processing (1 ton/month)	Unit (L/month)
White cotton	$30\ 10^3$
Colored or ecologic cotton	$9\ 10^3$

Table 3. Basic consumption of chemical products used in usual textile industry and the effluent which pollute the environment, compared to naturally colored cotton (source: adapted from Galindo *et al*. (2001) and Martins (1997)).

Chemical products	Basic consumption (t/month)	Basic Consumption (t/month/year)	Assumption (av. of 10% t/month)	Effluents (av. of 10% t/month/year)
Salt	60	720 10^3	12	144 10^3
Peroxide	8	96 10^3	1,6	19 10^3
Kelp	15	180 10^3	3	36 10^3
Acetic acid	3	36 10^3	0,6	7 10^3
Other acids	60	720 10^3	12	144 10^3
Reactive dyes	3.2	38 10^3	0,64	7,680
Sulfur dyes	6.9	82 10^3	1,38	16,560
Total	**312.2 t/month**	**1,873 10^3**	**31.22 t/month**	**374,640**

dyes and the most commonly found in the industries visited for their study. The author indicates that products, which are derived from sulfur dyes, exhibit more contaminated effluents, and presents the most chemicals used in textile production (Table 3).

A projection for the use of mesh chemicals for producing approximately 1000 tons of textile/month is projected in table 3.

Representing 25% of the Brazilian industrial sector, the textile segment of the state of Santa Catarina is one which somehow neglects the impact this activity may cause to the environment, producing excessive amounts of toxic effluents without treatment (Sauer, 2002). Estimation for the use of mesh chemicals for producing approximately 1000 tons of textile/month is projected showing a significant number of effluents, agreeing with Galindo *et al.* (2001) and Herrmann *et al.* (2011) and representing a significant impact on environmental contamination and aquatic life. The authors state that about 1% to 15% of the dyes used by the textile industries are lost in the dyeing process and, in overall, released in effluents, These findings also agree with other authors (Herrmann *et al.*, 2011), and table 4 shows data related to this issue.

These results on the reduction of polluted wastewater and water consumption would be an attractive argument for improving production of colored and agroecological cotton, or investing more in research and development of this product. However, the government's investment in new technologies is primarily directed to large agricultural enterprises, leaving the small farmers with little if none support.

Table 4 shows the use of water and waste dumped in nature in the past ten years, during the production of cotton. The production of cotton designed with the same consumption for the next 10 years is shown in table 5. Data on table 6 show cotton production with a reduction of 5%, which would be a possibility of increasing production of colored cotton, reducing water usage, and also projecting 5% reduction in waste over the next ten years.

In table 6, it can be observed the development of the next ten years, from one production of white cotton 5% lower than expected, which could be transformed

Table 4. Total of production, water consumption and chemical effluents in ten year ago with cotton production (source: IEMI (2012); Mapa (2012)).

Year	Production 1000 tons	H_2O Consumption 1000 tons	Chemical Effluents 1000 tons
2000/2001	1.511	543.960 10^6	566.081.10^6
2001/2002	1.245	448.200 10^6	466.426. 10^6
2002/2003	1.365	491.400 10^6	511.383. 10^6
2003/2004	2.099	755.640 10^6	786.369. 10^6
2004/2005	2.129	766.440 10^6	797.608. 10^6
2005/2006	1.038	373.680 10^6	388.876. 10^6
2006/2007	1.524	548.640 10^6	570.951. 10^6
2007/2008	1.602	576.720 10^6	600.173. 10^6
2008/2009	1.411	507.960 10^6	528.617. 10^6
2009/2010	1.194	429.840 10^6	447.320. 10^6
2010/2011	2.052	738.720 10^6	768.761. 10^6
Total	**17.170**	**6.181.200 10^6**	**6.432.568. 10^6**

Table 5. Projection, water consumption and chemical effluents in next ten years (source: adapted IEMI (2012), Mapa (2012)).

Year	Projection 1000 tons	H_2O Consumption 1000 tons	Chemical Effluents 1000 tons
2011/2012	2.155	775.800 10^6	807.349 10^6
2012/2013	1.563	562.680 10^6	585.562 10^6
2013/2014	1.543	555.480 10^6	578.069 10^6
2014/2015	2.309	831.240 10^6	865.043 10^6
2015/2016	2.504	901.440 10^6	938.098 10^6
2016/2017	1.912	688.320 10^6	716.311 10^6
2017/2018	1.892	681.120 10^6	708.818 10^6
2018/2019	2.658	956.880 10^6	995.793 10^6
2019/2020	2.853	1.027.080 10^6	1.068.847 10^6
2020/2021	2.261	813.960 10^6	847.061 10^6
2021/2022	2.241	806.760 10^6	839.568 10^6
Total	**23.891**	**8.600.760 10^6**	**8.950.524 10^6**

in cotton production and organic colored. It can also be noted the result in the reduction of water use of 70% (for these 5% less), and also assume a drop of 5% per year in the fall of effluents dumped in nature in the same period (Mapa, 2012).

The intensive use of the raw material for textile industries (Damiano, 2003), and the increasing interest by consumers in the use of green products (Demir *et al.*, 2010), has led to the augment in the research on colored fibers. The focus has been mainly to reduce the use of dyes, as it is a carcinogenic material (Ramalho *et al.*, 2010). However, the colors of the fibers influence the technological nature of the final product (Carvalho and Santos, 2003). According to Pan *et al.* (2010) genotypes, with colored fibers produce a higher amount of wax, which has a negative effect on the production of cellulose, reducing the quality of the fibers produced.

Table 6. Next 10 years with production 5 percent of colored and organic cotton and suppose reduction in use of water and 5% reduce year per year in chemical effluents (source: adapted IEMI (2012), Mapa (2012)).

Year	Projection 1000 tons	Consumption H_20 Reduce 70%	Chemical Effluents (mil/t) Reduction of 5% per year
2011/2012	2.047	736.918 10^3	766.888 10^6
2012/2013	1.484	534.238 10^3	555.965 10^6
2013/2014	1.465	527.398 10^3	548.847 10^6
2014/2015	2.193	789.478 10^3	821.585 10^6
2015/2016	2.378	856.078 10^3	890.893 10^6
2016/2017	1.816	653.758 10^3	680.346 10^6
2017/2018	1.797	646.918 10^3	673.228 10^6
2018/2019	2.525	908.998 10^3	945.966 10^6
2019/2020	2.710	975.598 10^3	1.015.274 10^6
2020/2021	2.147	772.918 10^3	804.352 10^6
2021/2022	2.128	766.078 10^3	797.233 10^6
Total	**22.690**	**8.168.384 10^3**	**8.500.581 10^6**

For these reasons, search the cotton fiber color shifts to other regions not only in Northeast Brazil and Embrapa Cotton led researchers to Paraná, because of the recent price increases of the product on site (Bellettini, 2011). The researchers sought to examine technological features of colored cotton with the potential to be grown in the northern State of Paraná, and according to the methodologies used, the colored cultivars obtained inferior in length (uniformity index and short fiber length and strength).

A study of Carvalho *et al.* (2005) also shows that the average colored cotton is 10% lower than white, as well as the characteristics of its fibers, are inferior. The author showed that genetic selection for stronger color intensity may results in negative effects on the fiber. Limited results on this subject are due to lack of studies using the colored cottons, which has been subjected to intense research and development as it occurred with the white fiber. Table 7 presents the chronological steps towards the development of the colored cotton in Brazil. There are cultivars being planted in the Northeastern of Brazil, in the state of Paraiba, in small family farms. Figure 1 shows various kinds of colors cotton fibers.

Fashion has been innovative in the use of synthetic fibers (composed by artificial, natural and mixed), but these innovations do not necessarily translate into environmental concerns. They only combine changes in relation to the style, the design, the artificial tissues, adding unique features for use

Table 7. Timeline of the development of colored fibers from 2001 to 2010 (source: Adapted from Beltrão e Carvalho (2004), Embrapa Algodão (2012)).

Year	Event
2000	Development of the variety BRS 200 Marron
2001	Fiber color begins commercial scale in Paraíba state by small farmers
2001	Fiber color reaches 30 to 40% higher price per pound relative to white fiber in 2002
2002	Development of the variety BRS Verde
2002	Cultivation of organic fiber begins (without chemicals or fertilizers)
2002	Fiber color reaches 200% higher price per pound relative to white fiber
2005	Development of the variety BRS Rubi
2010	Development of the variety BRS Topázio

Figure 1. Colorful cotton fibers produced from the manual choice of seedlings. The colors vary according to the planting site (source: Embrapa Algodão (2012)).

by health, sports and leisure, being supported by the chemical industry, electronics and even by nanotechnology. One feature that has been noted is the increasing use of chemical fibers at the expense of natural fibers, which have as a consequence more pollutants in industrial processes. The chemical fiber represented 62% of total consumption in 2006 to 39% in 1970, 44% in 1980 and 48% in 1990 (Garcia, 2009; Mariano, 2011).

A study of socially responsible consumption of clothing by Norum and Ha-Brookshire (2011) examined the effect of fiber origin, method of production and the price in consumer preference for cotton clothing in the USA. Results showed that the price appeared as the most important criteria for the purchase of cotton products (58.5%), transparency (30%) and fibers grown with sustainable methods were cited by only 11.5% of survey

3.2. Sustainability on fashion/apparel supply chain

Sustainability concepts have been discussed worldwide in several areas of knowledge and industrial production (Baskaran *et al.*, 2012; Gri, 2010; Mariano, 2011, Wced, 1987). The annual global sales of organic cotton products, for example, grew by over 40% between 2001 and 2009 (Ota, 2009).

The agroecologic cotton is produced in sustainable systems, with proper management and protection of natural resources, without the use of pesticides, genetically modified organisms, chemical fertilizers or other inputs harmful to human health, animal and the environment (Beltrão *et al.*, 2009, Cartaxo *et al.*, 2008). The cotton prices are defined internationally by the yarn quality which are related to the plant fibers, their length and reflectance. Produced under irrigation, cultivars with medium length fiber, cotton is not naturally white, and that makes the fiber is white and chemical methods are highly polluting, with bleaching products. If not for the action of man, there would be this level of whiteness in cotton yarn (Embrapa Algodão, 2012). There is a mutation of the cotton plant which makes possible the production of colored cotton. This production avoids dyeing process and saves water. The procedure was developed by Embrapa Cotton, Brazilian government agency which is specialized in technology transfer, and support family farming.

Being organic or with conventional management grown cotton plants (not genetically modified) are certified to be produced without the use of synthetic chemicals, the cultivation of cotton colored fiber in the Northeast of Brazil through family farming has developed in former years. It also modified the behavior of farmers, seeking more efficient ways of producing with reduced waste and avoiding chemicals. The farmers also get a good price on colored cotton, when compared to white fiber (Carvalho *et al.*, 2011). Thus, these products have attracted the attention of companies who care about environmental problems, valuing the clothing business and adding more value to the finished product (Refosco *et al.*, 2008).

The yarns produced from naturally colored fiber, undergoes fewer chemical processes, and it does not pollute the environment, besides representing a decrease of about 70% in the use of water, in the finishing process of the fabric. Currently, the social point of view, this production presents itself as a source of income for about a thousand farmers from the states of Paraíba, Pernambuco, Rio Grande do Norte and Ceará. No transgenic techniques are used in this development (Embrapa Algodão, 2012). A study by Embrapa Cotton, which analyzes the performance of commercial BRS Brown, a research of over 15 years in the field and the laboratory, showed that the technological characteristics of fiber and yarn are produced to meet the processing improvement (Organic Cotton, 2008; Refosco *et al.*, 2008; Mariano, 2011).

4. Final Remarks

Apparently 5% reduction in the production of white cotton, reverted to the production of organic cotton and colored, seems to represent little economy in every way, even to the general development of the country. Instead, a production of only 5% organic cotton and colorful world, could represent a drive revenue in small areas of family farming, spinning craft, producing handmade clothes and many other possibilities as objects of decoration and fashion accessories.

Furthermore, the water savings produced by this 5% of color cotton production and organic represent at least 70% total water used. Assuming that the development of the chemical industry would provide a 5% reduction in effluent thrown in nature in standard process, which does not exist in the production of colored cotton and organic, the result would be even more positive as the results of this study.

Getting into the era of sustainability has been a requirement for large companies that want to stay in business. The agroecological production of cotton is the embryo of an idea that could have an effect on this business network that moves millions worldwide. It still could provide Brazil the pioneer in this area, and improve the income of small and medium farmers, processing companies and clothing making, the entire chain of fashion.

The general awareness of people cause this change and new deeper studies on economic feasibility of production on a larger scale and colorful organic cotton, which is not yet available, one will be a pressing need to be addressed in future work on the topic.

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