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Moisture sorption in naturally coloured cotton fibres

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Abstract. Increasing environmental concerns have stimulated an interest in naturally coloured cottons. As many commercial and technical performance aspects of cotton fibres are influenced by their response towards atmospheric humidity, an in-depth research on moisture sorption behaviour of these fibres using dynamic vapour sorption is carried out. Significant differences were observed in sorption capacity and hysteresis behaviour of brown and green cotton fibres. These differences are mainly attributed to the variations in maturity and crystallinity index of the fibres. This study provides valuable insights into the moisture sorption behaviour of naturally coloured cotton fibres.

1. Introduction

Cotton is the most important natural fibre used in textile industry. Besides the traditional use as a textile material, cotton fits also in today's challenge to search for biopolymers or composites based on sustainable resources. Naturally coloured cotton, comprising fibres with natural pigments, are considered potential eco-friendly materials because the presence of natural pigments eliminates the need for colouring textile products to a certain extent, thus saving not only a large amount of energy but also preventing dye chemicals from polluting the environment. In the preceding years, the yields of naturally coloured cotton were low, and the fibres were too short to be machine-spun [1], [2]. However especially with advanced genetic breeding technologies naturally coloured cotton fibres in various shades (green and brown) with improved quality have been successfully produced [3], [4].

Even although much research is published on the moisture sorption of cotton fibres [5], [6], much less is known on the moisture sorption behaviour of naturally coloured cotton cultivars. As moisture in the fibre has a profound effect on almost all the mechanical properties (tensile strength, stiffness, etc.) as well as the physical (electric and thermal conductivity, etc.) and chemical ones (chemical reactivity, resistance to microbes, etc.) [7], a study on the moisture sorption of these fibres is also of high interest. Dynamic vapour sorption (DVS) is a well-suited technique to study the moisture sorption and the interaction of water molecules with a compound [8].

In the present study, DVS is successfully used to gain valuable information concerning moisture sorption behaviour of naturally coloured brown and green fibres. The moisture sorption profiles as well as the hysteresis behaviour are studied. The aim is to gain insights in the moisture sorption behaviour of naturally coloured cotton fibres as relevant for an optimal future material benefit.

2. Materials and Methods

Different shades of naturally coloured cotton (Gossypium hirsutum) fibres were supplied by Bayer CropScience N. V. (Ghent, Belgium). The plants were grown in similar conditions and harvested when mature. All fibres were used as received, without any pre-treatment. Cotton fibre properties were determined in Cirad (Montpellier, France). A high-volume instrument (HVI) is used to obtain micronaire values of cotton fibres. The maturity ratio of the fibres was determined using an advanced fibre information system (AFIS).

Dynamic vapour sorption (DVS) measurements were conducted in a Q-5000SA instrument (TA-instruments, Zellik, Belgium). All measurements were performed at 23 ± 0.1 °C. Deliquescent salts (sodium bromide and potassium chloride) were used to verify the humidity of the instrument.

The total hysteresis value was calculated by subtracting the area under the normalized desorption curve from the area under the normalized sorption curve using Microcal Origin 6.0 software (Microcal Software, Inc., Northampton, MA, USA).

The X-ray diffraction (XRD) patterns were measured for raw cotton fibres with an X-ray diffractometer (Thermo Fisher Scientific Inc, Waltham MA, USA) using CuKα radiation (λ=1.5406 A) at 40 kW and 20 mA. Scattered radiation was detected in the range of 2θ = 5-40^o, at a scan rate of 2^o/min. The crystallinity index (CI) was calculated as reported in literature [9].

3. Results and Discussions

The equilibrium moisture content (EMC) value at each interval is plotted against the relative humidity (RH) to draw the equilibrium isotherm for both brown and green fibres are shown in Figure 1. Although there are significant differences in the total amount of moisture present in the samples at a given RH, both fibres under investigation exhibit an S-shape curve with a distinct hysteresis. This finding is in line with our previous work on moisture sorption of both developing cotton fibres and brown ones [11] [12]. The differences in moisture sorption of brown and green fibres can be attributed to many factors of which OH accessibility is a significant component [11]. Thus, the effect of maturity and crystallinity will be looked at.

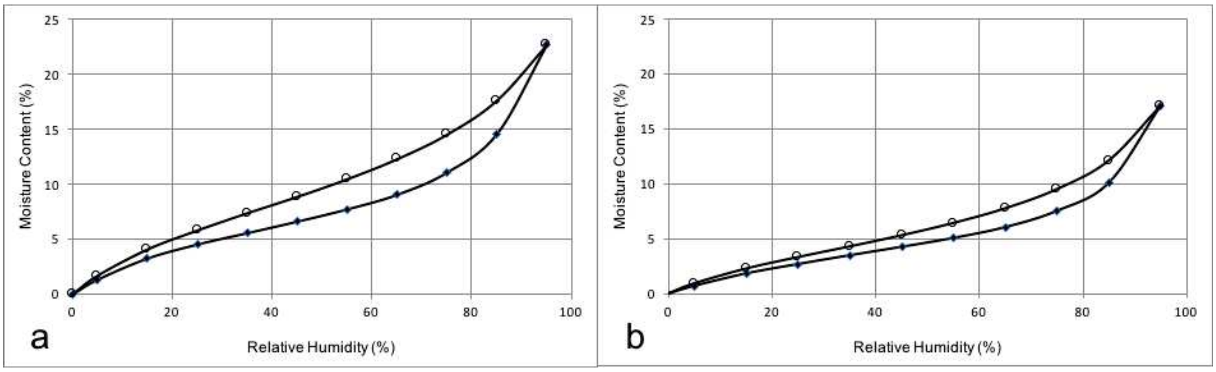

Figure 1. Moisture content (%) as a function of the relative humidity (%) for (a) brown (b) green cotton fibres

Table 1 lists the EMC at 95 % RH and the total hysteresis for both fibres. In addition, the maturity data measured by HVI (micronaire) and AFIS (maturity ratio) as well as the crystallinity index are given for each fibre.

The adsorbed water in the brown and green fibres produced an EMC of 23 and 17 % respectively, at the highest RH of 95 %. The EMC of the green cotton fibre is significantly lower than that of the brown cotton fibres. This may be attributed to the differences in maturity and crystallinity index values of the fibres. The maturity and crystallinity index values are lower for the brown fibre meaning the brown fibre has a less developed structure compared to the green fibre.

Table 1. EMC at 95 %, hysteresis, micronaire, maturity ratio, and crystallinity index data of brown and green fibres

	EMC at 95 % RH (%)	*Hysteresis*	Micronaire	*Maturity ratio*	Crystallinity index (%)
Brown	23	191.6	2.2	0.71	61
Green	17	101,6	2,4	0.77	70

Apart from differences in the sorption capacity, there are also differences in the hysteresis behaviour of the fibres. The brown fibre exhibits higher value of total hysteresis than the green one. This difference in the overall sorption hysteresis may be explained by the variations in the structural deformation of cell wall during sorption. As presented in Table 1, the crystallinity index, and thus the internal stability of the brown fibre is lower compared to the green fibre. Therefore, the extent of sorption and cell wall deformation would be greater for the brown fibre.

4. Conclusions

DVS was used to gain valuable information concerning the sorption behaviour of naturally coloured brown and green cotton fibres. Significant differences were observed in sorption capacity as well as hysteresis behaviour. These differences were attributed to the differences in maturity and crystallinity of the fibres. This study provides insights into the moisture sorption behaviour of naturally coloured cotton fibres.

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