

DYNAMIC MOISTURE SORPTION BEHAVIOUR OF DEVELOPING COTTON FIBRES

Özgür Ceylan¹ and Karen De Clerck²

¹Anadolu University, Faculty of Architecture and Design, Department of Fashion and Textile Design, Yunusemre Campus 26470 Eskişehir, Turkey

²Department of Materials, Textiles and Chemical Engineering, Ghent University, Technologiepark 907, 9052 Ghent, Belgium
ozgurceylan@anadolu.edu.tr, karen.declerck@ugent.be

Abstract: Dynamic vapour sorption is used to gain valuable information concerning the sorption behaviour of cotton fibres during their development. Moisture sorption isotherms for cotton fibres are obtained through dynamic vapour sorption analyser during their development stages. The developing cotton fibres exhibited variable dynamic moisture sorption behaviour. The sorption rate is found to be closely related to the structural and compositional changes in cotton fibres during their maturation process. This study provides valuable insights into the driving principles of the moisture sorption process of cotton fibres may aid to develop ways to improve the moisture management properties in general.

Keywords: moisture sorption, cotton, dynamic vapour sorption, sorption rate.

1 INTRODUCTION

Cotton is the premier natural fibre for textile applications mainly because of its biodegradable and renewable nature with a high-water absorption potential and light weight properties. 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.

Water sorption is expressed as moisture content and/or water retention value of textile fibres [1]. Water content in the fibre has a profound effect on almost all the mechanical properties (tensile strength, stiffness, ultimate elongation, etc.) as well as the physical (electric and thermal conductivity, isolation against UV radiation solubility, etc.) and chemical ones (chemical reactivity, resistance to microbes, etc.) [2]. Thus, a study on the moisture sorption is also of high interest for cotton fibres.

Previous research reported on the sorption behaviour of cotton fibres harvested at different stages in their development process. The moisture sorption profiles as well as the hysteresis behaviour were studied for the developing cotton fibres [3]. This knowledge will be further deepened in the present paper.

The main objective of this study is to examine the dynamic sorption behaviour of developing cotton fibres. Thus, the total running time of the sorption process and sorption rate for the developing fibres are studied extensively. The aim is to provide valuable insights in the moisture sorption mechanisms of the cotton fibre during their development process which may aid to develop ways to improve the moisture management properties in general.

2 MATERIALS AND METHODS

2.1 Materials

Cotton cultivar ST457 (*Gossypium hirsutum*) was grown in a green-house at 23°C and 15 kLux, with a 16 h/8 h day/night cycle). Flowers were tagged at anthesis and a few bolls were harvested at 15, 21, 36 and 80 days post anthesis (DPA).

2.2 Methods

Dynamic vapour sorption 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.

Four milligrams of cotton fibres, harvested at different stages during their development process, were rolled into a small ball and placed in the quartz sample pans. The humidity was increased stepwise, with steps of 10% relative humidity (RH) from 5 till 95%. The desorption isotherm, from 95 till 5%, was recorded as well. At every RH, the equilibrium moisture content (EMC) is monitored after reaching equilibrium, or thus when the weight change is less than 0.05% over a time period of 15 minutes.

3 RESULTS AND DISCUSSION

The response of the cotton fibre samples to a step change in RH in the sample chamber produces an asymptotic curve when plotted as moisture content against time, Figure 1. The total running time of sorption process for fibres with higher DPA is

noticeably lower than those of the lower DPA ones. This may be explained by the differences in availability of sorption sites due to structural and compositional changes in cotton fibres during their maturation process. At the early stages of development fibre growth is characterized by the synthesis of the primary cell wall and an increase in fibre length [4]. Once this phase is passed, around 21 DPA, the secondary cell wall growth initiates and the amount of cellulose increases quickly. This results in more structural organization thus less accessibility of water to the fibres. The variation in the total running time is closely related to the sorption ability, with higher levels of moisture sorption results in increases in the total run time [5].

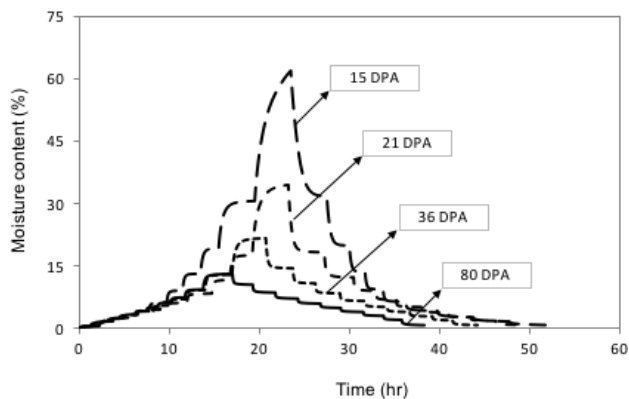


Figure 1 Change in moisture content as a function of time for developing cotton fibres

Increasing the RH, in each step of the sorption cycle, results in a new equilibrium condition within a specific time period for every sample. Dividing the increment or decrement of the moisture content at any RH by the time taken to reach the new EMC gives the sorption rate of materials [6].

At the lowest RH, similar sorption rates were observed for developing cotton fibres. At the higher end of the hygroscopic range, however, the differences in sorption rates were more pronounced, being higher for fibres with low DPA, and lower for fibres with high DPA. The higher sorption rate of the fibres with low DPA can mainly be attributed to the hygroscopic nature of the fibre components at this stage of development. The immature fibres contain next to 15-20% cellulose, also pectins, lignin, hemicelluloses and proteins [7]. This results in a loose and more open arrangement of micro fibrils thus a higher number of accessible OH groups per unit volume. A high proportion of non-cellulosic and the less crystalline cellulose content results in a loose and more open arrangements of the micro fibrils thus a more accessible structure for moisture sorption.

Also, the isotherm shape for low DPA fibres is found to be different from other natural fibres with it showing a rather type III isotherm instead of type II

according to IUPAC classification [3]. Materials exhibit type III isotherms, due to lack of cross-linking, can swell significantly at higher RH [8].

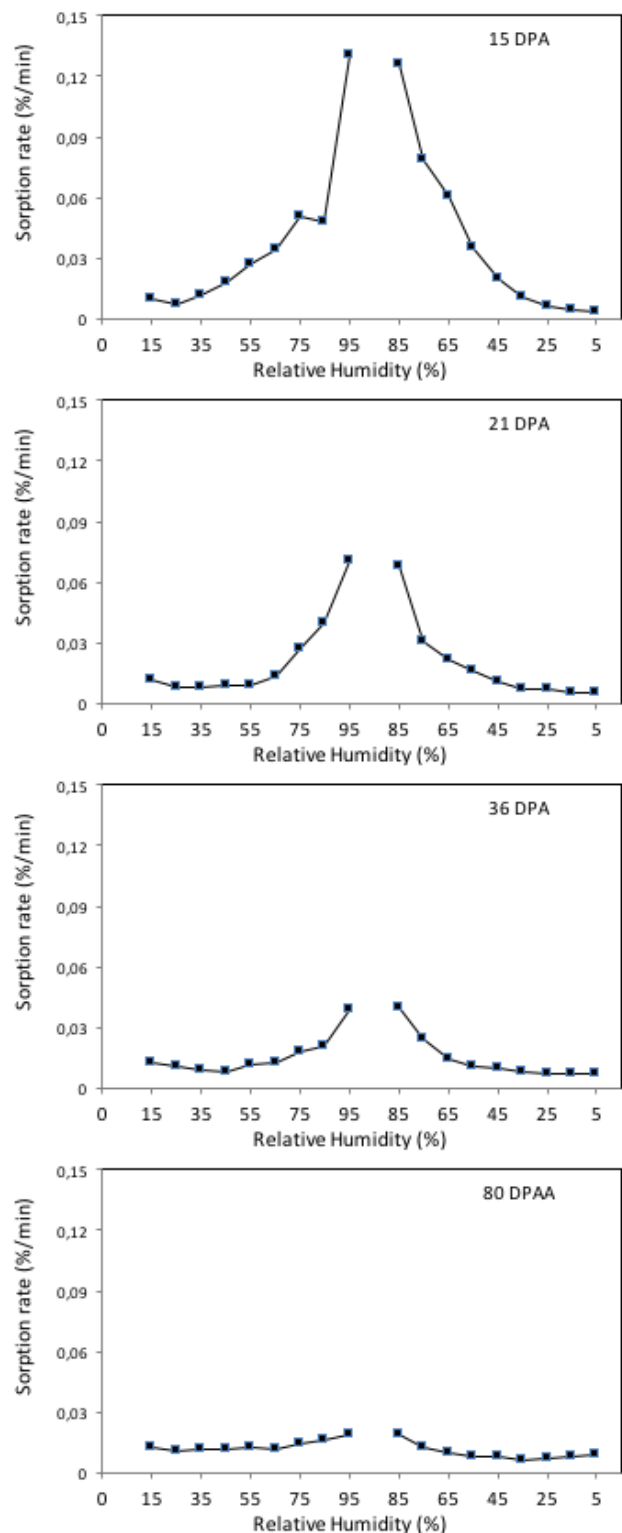


Figure 2 Sorption rate within a set of relative humidity during sorption process for developing cotton fibres

4 CONCLUSIONS

Dynamic vapour sorption can be used to gain valuable information concerning the dynamic moisture sorption behaviour of cotton fibres. Significant differences were observed in sorption time and sorption rate of developing cotton fibres. It is likely that these differences are closely related to the ratio between the cellulose crystalline and the amorphous zones as well as to the structural composition of the fibres. This study provides valuable insights to develop ways to improve the moisture management properties of cotton fibres in general. These improvements can lead further areas of application for cotton fibres such as composites due to the increasing demand on renewable sources, recyclability or biodegradability.

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