**Mathematical Modeling of the Technological Processes of the Primary Processing of Cotton Raw Material**

**Abdul-malik Kayumova)**

***Namangan State Technical University, Namangan, Uzbekistan***

***a)Corresponding author: jahongirsoloxiddinov20@gmail.com***

**Abstract.** This scientific work is devoted to the mathematical modeling of heat processes to improve product quality by optimizing the drying regime of cotton raw material. The model is based on full factorial experiments conducted under production conditions. It is possible to analyze the change in fiber and seed moisture at the minimum and maximum values of productivity along the technological flow, drying agent, and cotton raw material moisture in single and double drying, as well as their impact on the efficiency of cleaning and ginning. Based on the obtained mathematical models, an opportunity has been created for the first time to predict the processes of producing high-quality fiber and seed based on the initial moisture content of the cotton raw material and the productivity of the technological flow, and for the automation of cotton ginning plants.

**Keywords:** cotton raw material, seed, fiber, productivity, drying agent, temperature, heating, moisture, drying drum, mathematical modeling, full factorial experiment

**INTRODUCTION**

According to many researchers, the main task of the drying process is to bring the cotton moisture to 7-10%, depending on its variety and type, while maximally preserving the natural properties of the fiber and seed [1].

Initial studies [2] focused on the change in the temperature regime of cotton raw material and its components. The results showed that it is advisable to lower the drying agent temperature to increase it, and to use a low-temperature two-stage drying process necessary for processing and leveling the moisture. This is explained by the active contact of the cotton raw material with the drying agent in the drying zone of the drum, resulting in direct heating of the fiber with a large heat transfer surface, and passive heat between the beaters at the top of the drum, leading to uniform heating speed.

To ensure high accuracy of the recommended results, it is desirable for the ranges of the investigated parameters to be close. In the conducted study [3], the range of initial moisture content of cotton raw material was accepted as 10.5-22.3% with the aim of studying only the influence of the drying regime in the drying drum on fiber quality. In this case, the cleaning and ginning processes were carried out on laboratory equipment. Therefore, there is a need to conduct research under production conditions.

The moisture of cotton supplied to ginning plants ranges from 10.6 to 20% and above [1], therefore, moisture content from 10.0 to 21.0% was accepted, wherein cotton within this moisture interval is mainly processed by single or double drying. Based on the above, since the moisture content of cotton raw material is one of the research factors, it was included in the experimental design.

According to [1], based on the technological regulations for cotton processing, cotton ginning plants process cotton, mainly by variety, with a productivity of 7 t/h to 10 t/h. When a cotton ginning plant operates with a productivity of 7 t/h, drum drying units can operate in parallel with a productivity of 3.5 t/h for drying wet cotton. Furthermore, when processing wet cotton, the mechanism for conveying cotton along the cross-section and drum length varies at different productivities of the drying drum, which affects the drying intensity, change in cotton structure, and fiber quality. Therefore, the lower-level drying productivity of P=3.5 t/h and the upper-level productivity of P=10 t/h were included in the experimental design. For low-grade cotton raw material, processing is carried out up to a productivity of 9 t/h [1]. Therefore, for processing cotton with low-grade moisture of 14.3-21%, the lower-level drying productivity of P=3.0 t/h and the upper-level productivity of P=9 t/h were included in the experimental design.

The temperature of the drying agent is determined by the drying productivity, wherein high drying temperatures negatively affect the quality indicators of the fiber and products [4-8].

According to most authors, the use of drying agents at 200°C and above leads to changes in the quality and quantity indicators of the fiber. Therefore, the upper level T=200°C was accepted. The accepted lower level of the drying agent temperature T=100°C corresponds to the temperature at which the fiber quality indicators are maximally preserved.

Thus, as a result of experimental research and optimization of the drying process parameters, the following factors were accepted: initial moisture content of the cotton to be dried - X₁; productivity of the dryer for wet cotton - X₂; temperature of the drying agent - X₃ [3].

Tables 1-3 show the levels of the factors included in the experimental design.

**Single Drying of Cotton with 10-14.3% Moisture.**

**TABLE 1.** Factors included in the experimental design and their levels

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Designation** | **Factor Name** | **Variation Level** | | |
| **-1** | **0** | **+1** |
| Х1 | Initial moisture of cotton, % | 10,0 | 12,15 | 14,30 |
| Х2 | Productivity of drying drum for wet cotton P, t/h | 3,5 | 6,75 | 10,00 |
| Х3 | Temperature of drying agent T, °C | 100 | 150 | 200 |

**Double Drying of Cotton with 10-14.3% Moisture.**

**TABLE 2.** Factors included in the experimental design and their levels

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Designation** | **Factor Name** | **Variation Level** | | |
| **-1** | **0** | **+1** |
| Х1 | Initial moisture of cotton, % | 10,0 | 12,15 | 14,30 |
| Х2 | Productivity of drying drum for wet cotton P, t/h | 3,5 | 6,75 | 10,00 |
| Х3 | Temperature of drying agent T, °C | 80 | 110 | 140 |

**Double Drying of Cotton with 14.3-21% Moisture**

**TABLE 3.** Factors included in the experimental design and their levels

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Designation** | **Factor Name** | **Variation Level** | | |
| **-1** | **0** | **+1** |
| Х1 | Initial moisture of cotton, % | 14,3 | 17,65 | 21,0 |
| Х2 | Productivity of drying drum for wet cotton P, t/h | 3,0 | 6,0 | 9,0 |
| Х3 | Temperature of drying agent T, °C | 100 | 150 | 200 |

After selecting the main factors and their levels, it was also necessary to define the output parameters required for analyzing, evaluating, and optimizing the cotton drying process.

The results of experiments conducted under production conditions depend on the accuracy of monitoring all parameters and their stability. Each experiment was conducted with multiple checks of the drying process parameters.

The following were adopted as optimization parameters: moisture content of cotton raw material, % - Y₁; fiber moisture content, % - Y₂; seed moisture content, % - Y₃; fiber moisture content at the gin stand, % - Y₄; fiber heating temperature after drying, °C -- Y₅; seed heating temperature after drying, °C -- Y₆; fiber temperature at the gin stand, °C -- Y₇; total cleaning efficiency, % -- Y₈; cleaning efficiency for fine impurities, % -- Y₉; cleaning efficiency for coarse impurities, % -- Y₁₀; mass fraction of impurities and defective mixtures in the fiber, % -- Y₁₁ (Table 3.2.5). When planning the experiment, we assume that the function yields a linear model. The number of output parameters is such that there is no need for an experiment falling out by the random balance method, and the small number of experiments allows the use of a Full Factorial Experiment (FFE).

Experimental studies were conducted on a 2SB-10 model dryer.

In the experiment, the work productivity was ensured by the chronometry method, i.e., a productivity of P=10 t/h was achieved by dividing 5 tons of cotton into five parts for pneumatic transport and conveying each part continuously for 6 minutes.

A productivity of P=3.5 t/h was achieved by dividing 1.75 tons of cotton into five parts for pneumatic transport and conveying each part in one batch.

To partially compensate for errors incurred in the experiment, the experiments were conducted three times in a randomized order. Samples of cotton raw material were taken every 2 minutes along the processing flow from the drying drum, after the UHC cleaner, and at the gin stand, after the dryer started operating in the established mode, and the moisture and heat indicators of the cotton raw material and its components were determined operatively.

From the obtained samples, the quantity and quality indicators of the cotton and its components were determined. The remaining part of the sample was spread on shelves for drying under natural conditions.

The fine and coarse impurities separated during the cleaning process were weighed separately on a laboratory electronic scale.

A sample of fiber dried under natural conditions served as the control variant for comparing the obtained results.

All planned experiments were conducted with three repetitions.

After the experiment was conducted, the fiber and seed of the cotton raw material, the impurities of the initial cotton raw material, their physical-mechanical properties, and the mechanical damage of the seed were analyzed according to UzDSt and accepted methods.

Modern drying equipment, in terms of technological and design capabilities, does not have the ability to dry cotton to the required degree. Therefore, it is impossible to achieve the required moisture content from high-moisture cotton through a single drying process.

For double drying, factors similar to those in single drying were selected for experimental research and optimization of process parameters.

The temperature of the drying agent in the second drum was taken to be the same as in the first drum. Other parameters were also accepted as in single drying.

**MATHEMATICAL-STATISTICAL PROCESSING   
OF EXPERIMENTAL RESULTS**

Mathematical models based on the research results were obtained based on the methods of mathematical statistics [9].

The essence of the mathematical statistics method consists of determining the following:

The mean value and variance for the obtained random variables, which represent a sample from the general population, determined by the following formulas:

 (1)

 (2)

The calculated value of the Smirnov-Grubbs criterion was determined by the following formulas:

- to check for the maximum value that is radically different

 (3)

- to check for a radically different minimum value

. (4)

The hypothesis of homogeneity of the experimental matrix variance was checked using the Cochran criterion, its calculated value determined by the formula:

 (5)

Then the calculated value Fp is compared with the tabulated value Ft. If Fp < Ft, then the hypothesis of variance homogeneity, i.e., that the experiment was conducted with sufficient accuracy and correctly represents the process, is not rejected.

The regression coefficients were determined by the formula:

 (6)

 (7)

 (8)

Student’s t-test was used to check the significance of the regression coefficients, its calculated value  was compared with the tabulated value tt. If tᵣ > tt, then the significance of the regression coefficients is not rejected.

The calculated value of Student's t-test is equal to:

 (9)

For orthogonal matrices, the variances of the regression coefficients are the same, i.e.,  and are determined by the formula:

 (10)

where

 (11)

If the homogeneity of variances  is proven, then the variance of process repetition will be equal to

 (12)

Fisher's test was used to check the adequacy hypothesis, its calculated value Fp is compared with the tabulated value Ft. If Fp < Ft, then the adequacy hypothesis of the obtained mathematical model with probability Pd is not rejected.

The calculated value of Fisher's test is equal to:

, if > (13)

, if > (14)

**RESULTS**

Experimental studies were conducted under production conditions at the Uchkorgon cotton ginning plant according to the accepted planning matrix (FFE 2³) for single and double drying, according to the relevant technological regulations [1], the results of experiments, each repeated three times, are given in the appendix tables.

Regression equations based on the research results for each drying method and output parameters were obtained in a computer program.

**Single Drying of Cotton Raw Material with 10-14.3% Moisture**

Regression equations were obtained for the output parameters of the research results after single drying of cotton raw material with 10-14.3% moisture, and their expressions in real factor values are given:

**Moisture of Cotton, Fiber, and Seed after 2SB-10**

1. Cotton raw material moisture: Ycotton=9,48+1,675х1+0,91х2-0,69х3+0,105 х1х2-0,295х1х3-0,12 х2х3

2. Fiber moisture: Yfiber=5,768+1,12x1+1,082х2-1,163х3+0,115х1х2-0,25х1х3

3. Seed moisture: Yseed=10,81+1,973x1+0,798х2-0,476х3-0,159х1х3

4. Fiber moisture at the gin stand: Yfiber g/s=5,77+0,98x1+0,97х2-1,05х3 -0,268х1х3

**Heating of Fiber and Seed after 2SB-10**

5. Fiber heating temperature: Yfiber=50,833-1,667x1-3,5х2+13,167х3+1,0х1 х3-1,333х2х3

6. Seed heating temperature: Yseed=43,667-1,417x1-1,667х2+11,0х3-0,417х1 х2-0,75х1х3+0,5х2х3

7. Fiber temperature at the gin stand: Yfiber g/s=27,0+1,5x1+1,25х2+6,75х3-1,0х2хз -0,5х1х2х3

**Cleaning Efficiency**

8. Total: YTotal =77,83-2,43x1-4,695х2+2,47х3-0,57х1 х2

9. Cleaning efficiency for fine impurities: Yfine=76,56-4,06x1-5,76х2+3,75х3-0,91х1х2 +1,04х1х3- 0,83 х2х3

10. Cleaning efficiency for coarse impurities: Ycoarse=78,17-1,41x1-3,68х2+1,61х3-0,93х1х2 +0,58х2хз+0,4х1х2х3

11. Mass fraction of impurities and defective mixtures in the fiber: Yimpurities=2,59+0,593x1+0,29х2-0,157х3+0,117х1х2-0,06х1х3

**Double Drying of Cotton Raw Material with 10-14.3% Moisture**

Adequate regression equations were obtained for the output parameters of the research results after double drying of cotton with 10-14.3% moisture, and the following expressions are given:

**Moisture of Cotton, Fiber, and Seed after the First 2SB-10**

1. Cotton raw material moisture: =9,991+1,869х1+0,969х2-0,459х3-0,101х1 х3

2. Fiber moisture: =6,7+1,32x1+1,085х2-0,695х3+0,11х1 х2-0,15х1х3

3. Seed moisture: =11,094+2,0x1+0,90х2-0,174х3-0,1х2х3

**Moisture of Cotton, Fiber, and Seed after the Second 2SB-10**

4. Cotton raw material moisture: =7,994+1,594х1+1,544х**2-**0,724х3-0,144х1 х3

5. Fiber moisture:=5,105+0,915x1+1,26х2-0,715 х3-0,115х1х3

6. Seed moisture: =8,741+1,679x1+1,55х2-0,659х3-0,111х2х3

7. Fiber moisture at the gin stand: =5,168+0,809x1+1,094х2-0,638х3+0,04375x1x2-0,11875х1х3

**Heating of Fiber and Seed after 2SB-10**

**First Drum**

8. Fiber heating temperature: =40,0-1,0x1-2,25 х2+8,0х3-0,25х1х2-0,5х1х3-0,75х2х3-0,25х1х2х3

9. Seed heating temperature: =34,625-0,875x1-2,125х2+6,625х3-0,125х1х2-0,375х1х3+0,375х2х3-0,125х1х2х3

**Second Drum**

10. Fiber heating temperature: =50,625-1,375x1-4,875х2+9,125х3+0,125х1х2-0,875х1х3-0,875х2х3+0,125х1х2х3

11. Seed heating temperature: =46,25-1,0x1-4,25х2+7,75х3+0,5х1х2-0,5х1х3-0,25х2х3+0,5х1х2х3

12. Fiber temperature at the gin stand: =26,625+1,625x1+1,125х2+5,375х3+0,375х2х3

**Cleaning Efficiency**

13. Total: =84,79-3,02x1-3,92х2+2,5х3-0,655х1х2+0,26х2х3 -1,1х1 х2х3

14. Cleaning efficiency for fine impurities

= 84,64-4,12x1-5,74х2+3,28х3-1,864х1х2+0,57 x1x3-1,244х1х2х3

15. Cleaning efficiency for coarse impurities

=84,15-1,808x1-2,7х2+1,867х3-0,432х1х2+0,09 х1х3+0,13х2х3-0,911х1х2х3

16. Mass fraction of impurities and defective mixtures in the fiber

=2,175+0,497x1+0,245х2-0,152х3 +0,108х1х2 -0,05х1х3

**Double Drying of Cotton Raw Material with 14.3-21% Moisture**

Regression equations were obtained for the output parameters of the research results after double drying of cotton with 14.3-21% moisture, and their expressions are given:

**Moisture of Cotton, Fiber, and Seed after the First 2SB-10**

1. Cotton raw material moisture: =13,099+ 2,59х1+0, 894х2-0,724х3-0,16х1х3

2. Fiber moisture: =7,563+1,582 x1+1,225х2-1,118х3+0,19х1х2-0,202х1х3

3. Seed moisture: =15,37+2,967x1+0,695х2-0,43х3

**Moisture of Cotton, Fiber, and Seed after the Second 2SB-10**

4. Cotton raw material moisture: =9,428+1,933х1+1,455х2-1,125 х3 -0,26х1х3

5. Fiber moisture: =5,107+1,052x1+1,155х2-1,047 х3-0,197х1х3

6. Seed moisture: =10,72+2,227x1+1,42х2-1,035х3-0,203х1х3

7. Fiber moisture at the gin stand: =5,169+0,966x1+0,963х2-0,904х3 -0,236х1х3

**Heating of Fiber and Seed after 2SB-10**

**First Drum**

8. Fiber heating temperature: =47,625-2,375x1-3,875 х2+10,875х3-0,375х1х2-1,625х1 х3-1,125х2х3-0,125х1х2х3

9. Seed heating temperature: =44,75-2,25x1-2,5х2+5,5х3-0,5х1х2-0,5х1х3

**Second Drum**

10. Fiber heating temperature: =60,125-3,375x1-6,625х2+12,125х3+0,375х1х2-1,375х1х3-1,125х2х3

11. Seed heating temperature: =53,75-2,75x1-5,25х2+10,5х3 +0,25х1х2-1,5х1х3-1,0х2х3

12. Fiber temperature at the gin stand: =32,375+0,875x1+1,875х2+5,875х3+0,875х2х3-0,625 х1х2х3

**Cleaning Efficiency**

13. Total: =80,34-6,709x1-4,404х2+4,11х3+2,473х1х3+0,295х2х3

14. Cleaning efficiency for fine impurities: =81,92-7,94x1-6,47х2+5,61х3 +3,8х1х3-0,97х1х2х3

15. Cleaning efficiency for coarse impurities

=79,56-6,0x1-3,18х2+3,3х3+1,93 х1х3 +0,564х2х3+0,433х1х2х3

16. Mass fraction of impurities and defective mixtures in the fiber: =5,09+2,92x1+0,675х2-0,75х3+0,33х1х2 -0,62х1х3

**DISCUSSION**

The results of checking the variance of the initial parameters and the adequacy hypothesis of the obtained regression equations showed that all calculated values of the Fisher criterion are smaller than the tabulated ones. In turn, all obtained models are adequate.

To determine the influence of the drying stage, drying agent, and dryer productivity on cotton raw material and its components, previously obtained regression equations of the following form were analyzed.

It can be seen from the obtained regression equations that there are many output parameters, and it is necessary to determine which of them are more important and require optimization.

To find the correct solution to the problem, it is necessary to analyze the factors affecting cotton cleaning and ginning along with the drying regimes and determine the degree of their influence on fiber quality.

Drying regimes are a means of preparing cotton components, their moisture and temperature, in an optimal state. Therefore, a comprehensive approach is required here.

The purpose of the analysis is to determine the influence of drying regimes on the heating temperature values of cotton components, as well as their impact on the cleaning and ginning processes and fiber quality.

For this purpose, Tables 4 and 5 provide coefficients that allow determining the influence of factors, the main regime indicators of drying, on the output parameters, arranged according to the degree of influence.

**TABLE 4.** Coefficients of Regression Equations for Drying Cotton with 10-14.3% Moisture

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **№** | **Output Indicators** | **Coefficients** | | | | | | | |
| **b0** | **b1** | **b2** | **b3** | **b12** | **b13** | **b23** | **b123** |
| **Single Drying of Cotton** | | | | | | | | | |
|  | Y1 | 9,48 | 1,675 | 0,9 | -0,69 | 0,105 | -0,295 | -0,12 | - |
|  | Y2 | 5,768 | 1,12 | 1,082 | -1,163 | 0,115 | -0,25 | - | - |
|  | Y3 | 10,81 | 1,973 | 0,798 | -0,476 | - | -0,159 | - | - |
|  | Y4 | 5,77 | 0,98 | 0,97 | -1,05 | - | -0,268 | - | - |
|  | Y5 | 50,833 | -1,667 | -3,5 | 13,167 | - | 1,0 | -1,333 |  |
|  | Y6 | 43,667 | -1,417 | -1,667 | 11,0 | -0,417 | -0,75 | 0,5 | - |
|  | Y7 | 27,0 | 1,5 | 1,25 | 6,75 | - | - | -1,0 | 0,5 |
|  | Y8 | 77,83 | -2,43 | -4,695 | 2,47 | -0,57 | - | - | - |
|  | Y9 | 76,56 | -4,06 | -5,76 | 3,75 | -0,91 | 1,04 | 0,83 | - |
|  | Y10 | 78,17 | -1,41 | -3,68 | 1,61 | -0,93 | - | 0,58 | 0,4 |
|  | Y11 | 25,59 | 0,593 | 0,29 | -0,157 | 0,117 | 0,055 | - | - |
| **Double Drying of Cotton** | | | | | | | | | |
|  | Y1 | 7,994 | 1,594 | 1,544 | -0,724 | - | -0,144 | - | - |
|  | Y2 | 5,105 | 0,915 | 1,26 | -0,715 | 0,114 | -0,115 | - | - |
|  | Y3 | 8,741 | 1,679 | 1,55 | 0,659 | - | - | -0,111 | - |
|  | Y4 | 5,168 | 0,809 | 1,094 | -0,638 | - | 0,119 | - | - |
|  | Y5 | 50,625 | -1,375 | -4,875 | 9,125 | - | -0,875 | -0,875 | - |
|  | Y6 | 46,25 | -1,0 | -4,25 | 7,75 | 0,5 | - | - | 0,5 |
|  | Y7 | 26,63 | 1,625 | 1,125 | 5,375 | - | - | 0,375 | - |
|  | Y8 | 84,79 | -3,02 | -3,92 | 2,5 | -0,655 | - | 0,26 | -1,1 |
|  | Y9 | 84,64 | -4,12 | -5,74 | 3,28 | -1,864 | 0,57 | - | -1,244 |
|  | Y10 | 84,15 | -1,808 | -2,7 | 1,867 | -0,432 | - | - | -0,911 |
|  | Y11 | 2,175 | 0,497 | 0,245 | -0,152 | 0,108 | -0,05 | - | 0,06 |
|  | Y11 | 9,991 | 1,869 | 0,969 | -0,459 | - | -0,101 | - | - |
|  | Y21 | 6,7 | 1,32 | 1,485 | -0,695 | 0,11 | -0,15 | - | - |
|  | Y31 | 11,094 | 2,0 | 0,90 | -0,174 | - | - | -0,1 | - |
|  | Y51 | 40,0 | -1,0 | -2,25 | 8,0 | -0,25 | -0,5 | -0,75 | - |
|  | Y61 | 34,625 | -0,875 | -2,125 | 6,625 | - | -0,375 | 0,375 | - |

**TABLE 5.** Coefficients of Regression Equations for Double Drying of Cotton with 14.3-21% Moisture

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **№** | **Output Indicators** | **Coefficients** | | | | | | | |
| **b0** | **b1** | **b2** | **b3** | **b12** | **b13** | **b23** | **b123** |
|  | Y11 | 13,099 | 2,59 | 0,894 | -0,724 | - | -0,16 | - | - |
|  | Y21 | 7,563 | 1,582 | 1,225 | -1,118 | 0,19 | -0,202 | - | - |
|  | Y31 | 15,37 | 2,967 | 0,695 | -0,43 | - | - | - | - |
|  | Y51 | 47,625 | -2,375 | -3,875 | 10,875 | -0,375 | -1,625 | -1,125 | - |
|  | Y61 | 44,75 | -2,25 | -2,5 | 5,5 | -0,5 | -0,5 | - | - |
|  | Y1 | 9,428 | 1,933 | 1,455 | -1,125 | - | -0,26 | 0,1 | 0,102 |
|  | Y2 | 5,107 | 1,052 | 1,155 | -1,047 | - | -0,197 | - | - |
|  | Y3 | 10,72 | 2,227 | 1,42 | -1,035 | - | -0,203 | - | - |
|  | Y4 | 5,169 | 0,966 | 0,963 | -0,904 | - | -0,236 | - | - |
|  | Y5 | 60,125 | -3,375 | -6,625 | 12,125 | 0,375 | -1,375 | -1,125 | - |
|  | Y6 | 53,75 | -2,75 | -5,25 | 10,5 | 0,25 | -1,5 | -1,0 | - |
|  | Y7 | 32,375 | 0,875 | 1,875 | 5,875 | - | - | 0,875 | -0,625 |
|  | Y8 | 80,34 | -6,709 | -4,404 | 4,11 | - | 2,473 | 0,295 | - |
|  | Y9 | 81,92 | -7,94 | -6,47 | 5,61 | - | 3,8 | - | 0,97 |
|  | Y10 | 79,56 | -6,0 | -3,18 | 3,3 | - | 1,93 | 0,564 | 0,433 |
|  | Y11 | 5,09 | 2,92 | 0,675 | -0,75 | 0,33 | -0,62 | - | - |

**CONCLUSION**

The analysis of the regression equations showed that the initial moisture content of the cotton raw material (x₁) has a significant influence on the moisture content of the cotton raw material and its components after drying (Y₁, Y₂ and Y₃); the higher the initial moisture content, the higher the moisture content of the cotton raw material and its components. As the number of drying stages increases, the influence of the initial cotton moisture content (x₁) on the Y₁-Y₃ parameters decreases.

For single drying (with initial moisture of 10-14.3%), the regression coefficient for cotton raw material moisture (Y₁) is b₁ = 1.869; for double drying it is 1.594 (for cotton raw material moisture (Y₁) with initial moisture of 14.3-21.0%, the regression coefficient b₁ = 2.59; for double drying it is 1.933). For fiber moisture (Y₂) in single drying (for cotton raw material with initial moisture of 10-14.3%) b₁ = 1.32; in double drying 0.915 (for cotton raw material moisture (Y₂) with initial moisture of 14.3-21.0%, the regression coefficient b₁ = 1.582; in double drying 1.052). For seed moisture (Y₃) in single drying (with initial moisture of 10-14.3%) b₁ = 2.0, in double drying 1.679 (for cotton raw material moisture (Y₃) with initial moisture of 14.3-21.0%, the regression coefficient b₁ = 2.967; in double drying 2.227). The decrease in the regression coefficient b₁ with an increase in the number of drying stages can be explained by the decrease in the moisture content of the cotton raw material and its components, which is considered as the initial moisture in the subsequent drying process, due to the removal of moisture in the previous drying process as residual moisture.

Similarly, the temperature of the drying agent has a great influence on the moisture content of the cotton raw material and its components after drying. The higher the temperature of the drying agent, the lower the moisture content of the cotton raw material and its components. However, the influence of the drying agent temperature on the moisture content of the cotton raw material and its components is not the same. For example, in single drying (for cotton raw material with initial moisture of 10-14.3%), the regression coefficient for fiber moisture is b₃= 0.695, for cotton raw material moisture it is 0.459, and for seed moisture it is 0.174 (for cotton raw material with initial moisture of 14.3-21.0%, the regression coefficient for fiber moisture is b₃=1.118, for cotton raw material moisture it is 0.724, and for seed moisture it is 0.695). This indicates that an increase in the drying agent temperature leads to a rapid decrease in fiber moisture, while the rate of decrease in the moisture content of the cotton raw material and seed is very slow.

In double drying of cotton raw material (for cotton raw material with initial moisture of 10-14.3%), the regression coefficient for drying agent temperature X₃ is b₃=0.724; for seed moisture 0.659 and for fiber moisture 0.715 (for cotton raw material with initial moisture of 14.3-21.0%, the regression coefficient for drying agent temperature X₃ for fiber moisture is b₃=1.125; for seed moisture 1.035 and for fiber moisture 1.047). These show that increasing the number of drying stages allows for more uniform drying of the cotton and its components.

The productivity of the drying drum for wet cotton raw material (X₂) also has a significant impact on the moisture content of the cotton raw material and its components after drying. It can be seen from the regression equations (Y₁ Y₂ and Y₃) that in single drying of cotton (for cotton raw material with initial moisture of 10-14.3%), the productivity of the drying drum for wet cotton raw material has a greater influence on fiber moisture (b₂=1.085) compared to cotton raw material (b₂= 0.969) and seed (b₂=0.90) moisture (for cotton raw material with initial moisture of 14.3-21.0%, the productivity of the drying drum for wet cotton raw material has a greater influence on fiber moisture (b₂=1.225) compared to cotton raw material (b₂=0.894) and seed (b₂ =0.695) moisture). From these results, it can be concluded that the higher the moisture content of the cotton raw material in the drying drum, the higher the fiber moisture will be. Consequently, to prevent the fiber from over-drying, it is advisable to operate the drying drum at high productivity for wet cotton raw material. It can be seen from the regression equations that in double drying (for cotton raw material with initial moisture of 10-14.3%), for cotton raw material b₂= 1.544, for fiber moisture b₂= 1.26 (for cotton raw material with initial moisture of 14.3-21.0%, for cotton raw material b₂= 1.455, for fiber moisture b₂= 1.155).

The initial moisture content of the cotton raw material (X₁) and the drying agent temperature (X₃) together have a negative interactive effect on the moisture content of the cotton raw material and its components after drying.

Also, the analysis of the regression equations shows that in single drying, an increase in the drying agent temperature and a decrease in productivity for wet cotton raw material increase moisture removal. The fiber dries faster than the seed because the fiber is in direct contact with the drying agent and heats up quickly.

**REFERENCES**

1. Hernández-Bautista, G., García-Montalvo, I. A., Pérez-Santiago, A. D., Sánchez-Medina, M. A., Matías-Pérez, D., Alpuche-Osorno, J. J., Torres, S. S., & Hernandez-Bautista, E. (2021). Numerical Simulation of Dyeing Process of Cotton with Natural Dye. Processes, 9(12), 2162. <https://doi.org/10.3390/pr9122162>
2. Kayumov, A. (2023). Effect of drying regime on moisture of components of cotton. AIP Conference Proceedings, 2789, 030010. <https://doi.org/10.1063/5.0145748>
3. Karimov, N., Kayumov, A., & Mamadjanov, S. (2024). Development of theoretical model of cotton movement in pneumotransport and separation process. AIP Conference Proceedings, 3045, 030047. <https://doi.org/10.1063/5.0198415>
4. Quliyev, T. M., Maqsudov, E. T., Jumaniyazov, Q., Djumabayev, G. X., Korabayev, Sh. A., & another author. (2025). Optimization of twist triangle geometry and drafting system for enhanced yarn quality in ring spinning. Izvestiya Vysshikh Uchebnykh Zavedenii, Seriya Teknologiya Tekstil'noi Promyshlennosti, (3), 157–164. <https://doi.org/10.47367/0021-3497_2025_3_157>
5. Utashov, Z., Usmonkulov, A., Djamolov, R., & Egamberdiyev, F. (2023). Study on the effect of cotton fiber temperature on cleaning effects. IOP Conference Series Earth and Environmental Science, 1142(1), 012087. <https://doi.org/10.1088/1755-1315/1142/1/012087>
6. Sevostyanov, A. G. (2007). Methods and means for researching processes in the textile industry. Moscow State Textile University named after A.N. Kosygin.
7. Mirzaraxmatovich, S. M. (2022). Determination of Technological Parameters of Fiber Separation Device from Cotton Waste. Engineering, 14(11), 510–522. <https://doi.org/10.4236/eng.2022.1411038>
8. Veliev, F. (2023). A theoretical method of describing the interaction of raw cotton with moving working bodies of cotton-cleaning machines. EUREKA Physics and Engineering, 1, 76–85. <https://doi.org/10.21303/2461-4262.2023.002756>
9. Mamatov, A., Parpiev, A., & Kayumov, A. (2020). Mathematical Models of the Heat and Mass Exchange Process During Pneumo-Transportation of Cotton-raw. Theoretical & Applied Science, 11(91), 508–514. <https://doi.org/10.15863/TAS.2020.11.91.79>