

TECHNOLOGICAL BASES FOR CULTIVATING INDUSTRIAL HEMP STALKS AND PRODUCING HIGH-QUALITY HOMOGENEOUS FIBER UNDER THE SOIL AND CLIMATIC CONDITIONS OF THE SURKHANDARYA REGION

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Abstract This extended thesis covers the determination of the anatomical, morphological, and decortication characteristics of industrial (non-narcotic) hemp stalks grown under the hot, dry climate and irrigated, saline soil conditions of the Surkhandarya region, as well as the technological parameters for producing one-type (homogeneous) hemp fiber. The research scientifically substantiates the mathematical models and physical-mechanical indicators of stalk discretization (cutting into 55–60 cm segments), disintegration under sliding bending forces, and aerodynamic-inertial separation to remove hurd (shive) and dust.

Keywords: *Surkhandarya, industrial hemp, hemp fiber, disintegration, aerodynamic separation, discretization, hurd content, technical length, inflorescence, linear density, resource saving.*

1. INTRODUCTION AND RELEVANCE OF THE PROBLEM

In the global textile and composite materials industries, the demand for natural bast fibers—particularly eco-friendly hemp fiber with high tensile strength—is growing by 12–15% annually. The Surkhandarya region, with its unique soil and climatic conditions featuring high solar radiation (over 3,200 hours of sunshine per year), elevated temperatures, and irrigated farmland, possesses immense potential for obtaining high biological and technical yields of industrial hemp.

Hemp stalks contain 70–75% cellulose, making them a rapidly renewable resource that regenerates 5–7 times faster than wood. However, under the hot and dry atmospheric conditions of Surkhandarya, harvested hemp straw and ret (stalks) experience a sharp decline in moisture content (down to 8–10%), rendering the stalks brittle. Processing such dry stalks using conventional roller breaking and scutching machines (such as KPP-3, KPP-4) leads to

severe fiber fragmentation, a 30–35% reduction in total fiber yield, and the generation of large quantities of waste (hurd-fiber mixture).

To address this issue, it is vital to develop and implement an advanced, resource-saving technological chain for producing **homogeneous (one-type) hemp fiber**. This process adapts to the morphological structure of hemp stalks grown in arid regions through stalk fractioning, disintegration, and aerodynamic separation.

2. RESEARCH METHODOLOGY AND OBJECTS

The research objects were monoecious industrial hemp varieties free of narcotic substances (THC < 0.1%)—namely "Ingreda" (yellow-stemmed) and "Yuliana" (green-stemmed)—cultivated on irrigated meadow-silt soils in the Surkhandarya region.

The following scientific and laboratory methods were employed:

1. **Anatomical and Morphological Analysis:** Total stalk length, technical length, stalk diameter at the butt (komel), middle, and top (inflorescence) sections, wall thickness, and internode distances were measured in accordance with GOST 27024-86 and analyzed using an "R20" optical microscope.
2. **Physical-Mechanical and Decortication Properties:** Tensile strength of bast and hemp fiber (on an IR 5062-0.5 tensile tester with a 100 mm gauge length), linear density (tex), flexibility, and fiber-to-wood bond strength were evaluated using a modified OOV testing apparatus and dynamometers.
3. **Mathematical and Statistical Processing:** Experimental data reliability was verified using MathCAD 14, STATISTICA 6.0, and MS Excel software packages at a confidence level of $P \leq 0.05$.

3. RESEARCH RESULTS AND DETAILED ANALYSIS

The study revealed that under hot and dry climatic conditions, hemp varieties exhibit high growth rates, but the stalk structure and fiber properties show significant variation along the length of the stem (high degree of heterogeneity).

Table 1.

Morphological indicators of hemp varieties (average values)

Indicators	"Ingreda" (Technical Ripeness)	"Yuliana" (Technical Ripeness)	"Ingreda" (Biological Ripeness)	"Yuliana" (Biological Ripeness)

Total length, cm	173.6 ± 2.4	165.7 ± 3.22	179.8 ± 2.50	216.7 ± 8.70
Technical length, cm	81.5 ± 3.40	94.9 ± 2.70	100.9 ± 2.80	167.6 ± 6.40
Inflorescence (top) length, cm	92.1 ± 2.80	59.8 ± 4.10	78.9 ± 5.00	49.1 ± 3.30
Inflorescence share of total length, %	53.0	36.1	43.8	22.6
Butt (komel) diameter, mm	8.4 ± 0.3	7.9 ± 0.2	9.8 ± 0.4	9.2 ± 0.3
Middle diameter, mm	6.2 ± 0.2	5.8 ± 0.2	7.1 ± 0.3	6.5 ± 0.2

As shown in Table 1, the inflorescence zone accounts for up to **53.0%** of the total stalk length in the "Ingreda" variety. Anatomical analysis indicated a dense distribution of leaf and branch traces within the inflorescence region. Bast fibers in this top zone consist primarily of short, scattered secondary fibers with **2.2–2.5 times lower tensile strength** compared to primary fibers in the technical section. Laboratory evaluation of fibers extracted from the butt, middle, and top sections established the following patterns:

Tensile Strength: Specific tensile strength reaches 28.5–32.4 kgf/mm² in the middle and butt sections, whereas in the inflorescence section it drops to 11.2–13.5 kgf/mm².

Wood-Bast Adhesion: The force required to detach bast from wood in the technical length section is relatively low (\$120-140\$ N/m), while in the inflorescence section, due to intertwined tissue structures, adhesion increases to \$220-250\$ N/m.

Consequently, feeding whole, intact stalks into conventional breaking and scutching machinery is technologically inefficient, resulting in severe fiber damage and degraded fiber quality.

PROPOSED HOMOGENEOUS FIBER PROCESSING TECHNOLOGY AND PARAMETERS

Based on research findings, a **4-stage resource-saving technological scheme** was substantiated for primary hemp processing in Surkhandarya:

| STAGE 1: Stalk Fractioning & Discretization (55–60 cm) |



| STAGE 2: Mechanical Decortication in Disintegrator |



| STAGE 3: Aerodynamic & Inertial Separation Cleaning |



| STAGE 4: Final Shaking (Scutching), Quality Control & Baling |

Stage 1: Stalk Fractioning and Discretization

1. **Fractioning:** Stalks are pre-separated into two distinct fractions: the *technical length* section and the *inflorescence* section.
2. **Discretization (Cutting):** Stalks are cut into uniform segments of **55–60 cm**.
3. **Rationale:** Theoretical calculations demonstrate that 55–60 cm stalk segments allow even distribution of impact and bending forces within the disintegrator chamber. This prevents fiber tangling and increases the surface area for hurd detachment by 40%.

Stage 2: Mechanical Decortication in a Disintegrator

- **Equipment Principle:** Traditional multi-roller breakers are replaced with a high-speed disintegrator featuring bladed rotors.
- **Deformation Mechanism:** Stalk segments undergo *high-frequency impacts* combined with *sliding bending (bending-shearing)* deformations.
- **Operating Parameters:** Rotor speed is set to **800–1000 rpm**, with a clearance gap of **6–8 mm** between impact blades and the grate bars. Brittle wood (hurd) breaks down into fine particles, while strong, flexible hemp fiber remains undamaged.

Stage 3: Aerodynamic Separation and Dust Removal

- **Challenge:** Disintegration yields a mixture containing 60–70% fragmented hurd and high concentrations of organic dust.
- **Aerodynamic Separator:** A closed-loop separator operating on aerodynamic and centrifugal-inertial forces was developed.
- **Working Mechanism:** The material stream enters an air duct with airflow velocities maintained at $v = 8.5 - 10.2$ m/s. Denser hurd particles and heavy dust drop into a lower hopper due to inertial force, whereas light, supple bast fibers are collected on a perforated screen drum.
- **Performance:** Hurd content in the fiber stream drops from **260–280% down to 110–130%**, while workplace dust emissions are reduced by 90%.

Stage 4: Final Shaking and Baling

The pre-cleaned fiber passes through a 2–3 section shaking machine to remove residual hurd ($< 3.5\%$) before being hydraulically pressed into standard bales weighing 100–120 kg.

TECHNOLOGICAL, ECOLOGICAL, AND ECONOMIC EFFICIENCY

A comparative evaluation between conventional processing lines and the proposed disintegrator-based technology is presented in Table 2:

Table 2.

Comparative technological performance indicators

Indicator	Conventional Method (KPP Line)	Proposed Disintegrator Method
Processed fiber yield, %	18.0 – 20.0	26.5 – 28.5
Fiber tensile strength, kgf	14.5 ± 1.2	23.2 ± 1.4
Linear density, tex	18.5 – 22.0	12.5 – 14.0

Fiber uniformity (hourly variation coefficient), %	28.5	11.2
Final hurd content, %	8.0 – 12.0	2.5 – 3.5
Machinery metal mass, tonnes	18.5	9.2
Energy consumption (per 1 t fiber), kWh	480 – 520	290 – 310
Reduction in production cost per 1 t fiber, %	Baseline	22.5 – 25.0% lower

MAIN CONCLUSIONS

Industrial hemp varieties ("Ingreda" and "Yuliana") grown in Surkhandarya exhibit a high proportion of inflorescence (36–53%), which displays significantly different physical properties from the technical stem section.

Stalk discretization into **55–60 cm** segments represents the optimal parameter for maximizing hurd separation while preserving fiber integrity during disintegration.

Processing discretized stalks in a disintegrator via sliding bending forces combined with aerodynamic separation raises total fiber yields to **26.5–28.5%**.

The proposed technological chain cuts electrical power consumption by **30–35%**, reduces machinery mass by **45–50%**, and lowers fiber production costs by **22–25%** compared to traditional lines.

The extracted homogeneous hemp fiber exhibits high tensile strength and low linear density, rendering it fully suitable for textile yarns, biocomposites, and eco-friendly construction materials.

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