DESIGN AND EXPERIMENT OF COMB-BRUSH AIR-SUCTION COMPOSITE FLAX CAPSULE HARVESTING TEST BENCH

梳刷气吸复合式亚麻（胡麻）蒴果收获试验台设计与试验

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ABSTRACT

In view of the problem of plant entanglement threshing roller in the process of mechanized flax harvesting, a comb-brush air-suction composite flax capsule harvesting test stand was designed based on the harvesting method of harvesting capsules independently and then breaking the capsules to thresh them. The following four parameters were selected as experimental factors: the shape of comb tooth cross-section, the rotational speed of comb roller, the relative speed of machine travel and the air volume of centrifugal fan. The following four indicators were chosen as the experimental indicators: capsule removal rate, capsule breakage rate, capsule collection rate and plant winding rate. A four-factor and three-level orthogonal test was conducted. The results showed that the optimal combination of test factors was as follows: the shape of comb tooth cross-section was rectangular, the rotational speed of the brush roller was 90 rad/min, the speed of machine travel relative to the plant was 80 mm/s and the air volume of centrifugal fan was 6000 m^3/h. Under the condition of better experiment parameters combination, the capsule removal rate was 96.45%, capsule shell breaking rate was 98.79%, capsule collection rate was 95.65% and flax plants winding rate was 2.52%. The comb-brush air-suction composite flax capsule harvesting test bench provided the feasibility scheme for the problem of plant winding thresher roller and capsule collection.

摘要

针对亚麻（胡麻）机械化收获过程中植株缠绕脱粒滚筒问题，基于先独立收获蒴果、再对蒴果破壳脱粒的收获方式，设计了一种梳刷气吸复合式亚麻（胡麻）蒴果收获试验台。以梳齿截面形状、梳刷滚筒转速、机具行进相对速度、离心式通风机风量为试验因素，以蒴果脱尽率、破壳率、收集率、植株缠绕率为试验指标，进行四因素三水平正交试验。正交试验结果表明：较优试验因素组合梳齿截面形状为矩形、梳刷滚筒转速为 90 rad/min、机具相对植株行进速度为 80 mm/s、离心风机风量为 6000 m^3/h；在较优试验因素组合作业条件下，蒴果脱尽率为 96.46%、蒴果破壳率为 98.91%、蒴果收集率为 95.66%、植株缠绕率为 2.52%。梳刷气吸复合式亚麻（胡麻）蒴果收获试验台提供了解决亚麻（胡麻）植株缠绕滚筒和蒴果收集问题的可行性方案。

INTRODUCTION

At present, foreign flax mechanized harvesting mode mainly consists of two-stage harvesting and combined harvesting, among them, the two-stage harvesting is mainly to harvest flax firstly and then lay it in the field for 2~3 days, then it is picked up and harvested by traction or self-propelled combined harvester with pick up function. Meanwhile, foreign flax harvesting equipment has high intelligence level, complex operation control system and high price, which are not suitable for a wide application of Chinese flax mechanized production equipment (*Dai., 2020*). Currently, in China, research on flax harvesting is mainly based on full-feed and half-feed harvest, for example, the machine was designed for separating and cleaning different components of flax threshing material in the harvest period (*Dai et al., 2019; 2020*). The full feeding type flax thresher is designed for the problem of small flax seed, easy winding stem and poor feeding fluidity (*Shi et al., 2019*). According to the agronomic requirement of flax retting production, the 5YF-150 traction flax retting and threshing machine was designed (*Zhang et al., 2008*). In order to realize the goal of flax picking, threshing and laying, a traction type flax threshing machine was designed (*Zhao et al., 2010*). In view of the problems such as small land area, narrow roads, difficult transportation, difficult transfer and difficult operation of the large

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combine harvester, flax stalk is easy to be wound and blocked, difficult to feed and so on, the crawler type flax combine harvester be applied to hilly and mountainous areas was designed (*Shi et al., 2021*). There are problems both in terms of winding the threshing roller when feeding the plant and blocking the sieve plate when cleaning the material due to complex impurities, therefore the plant twining roller is an urgent problem to be solved in mechanized flax harvesting (*Xu et al.,2021*).

Aimed at the aforementioned problem of plant winding roller in mechanized flax harvesting, the purpose of this study is to design a flax capsule harvesting test bench based on the methods that the flax capsule was harvested independently first and then threshed.

MATERIALS AND METHODS

Experiment materials, conditions and equipment

Fig. 1 - Comb-brush air-suction composite flax capsule harvest test bench

The mature blue flax plants with 15.33% moisture content were selected as test materials, it is also called perennial root flax (*Linum perenne* L.*var.sibiricum* Planch.) which is a perennial herb of flax genus in flax family, its plant and capsule characteristics are similar to flax. The test site was chosen in the Mechanical Design Laboratory of the College of Agricultural Engineering, Shanxi Agricultural University. Test equipment includes the comb-brush air-suction composite flax capsule harvesting test bench (Fig. 1 -), electric air blowing drying oven, electronic balance (precision 0.01 g). The experimental data processing software includes Microsoft office Excel 2019 and Statistical Analysis System 9.1.

Overall structure and working principle of experiment equipment

The working parts of the test bench mainly include brushing device, collection system, power system, delivery system and control system. It mainly consists of machine frame, brush roller, protective cover of brush roller, V belt, big belt wheel, small belt wheel, variable speed belt wheel, plant conveyor guide rail, plant holding device, centrifugal fan, electromagnetic variable-speed motor, three-phase asynchronous motor, stepper motor and other structures. (Fig. 2 -)

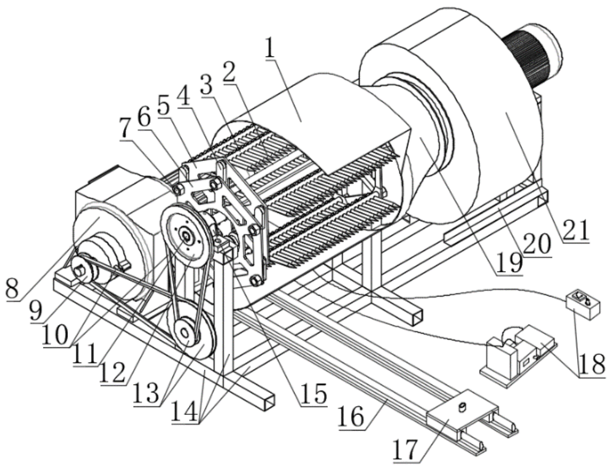

Fig. 2 - Comb-brush air-suction composite flax capsule harvesting test bench

1-Brush roller protection cover; 2-Comb tooth; 3-Comb tooth rack; 4-Fittings; 5-Active hexagonal disc; 6-Driven hexagonal disc; 7-Driven shaft; 8-Motor; 9-Small pulley; 10-The belt; 11-Roller shaft; 12-The big belt wheel; 13-Variable speed pulley; 14-Machine frame; 15-Bearing; 16-Conveying guide rail; 17-Holding device; 18-The controller; 19-Fan interface; 20-Fan frame; 21-Centrifugal fan

When the test bench is working, the brush roller rotates under the power which is output from the motor through the belt drive to the brush roller shaft via the variable speed pulley. The comb teeth of the brushing roller does parallel movement under the constraint of the parallel four-bar mechanism, the translating comb teeth act on the clamped plants of the conveyor rail. The plant keeps close contact with the comb tooth under the wind power action of the centrifugal fan, which is beneficial for the plant be brushed better. Under the protection of the brush roller protection cover, the removed capsule falls into the protective cover or rests on the surface of the comb tooth, under the action of the centrifugal fan with specific wind pressure, capsules are collected to a specified position, at the same time, under the strong wind force of the centrifugal fan, there is a large impact force between the capsule and the fan blade, therefore, the collected capsule material belongs to the semi-threshing material which is conducive to the subsequent stage of capsule breaking and threshing.

The main technical parameters of the comb-brush air-suction composite harvesting test bench of flax capsule are listed in Table 1.

Table 1

Main technical parameters of comb-brush air-suction composite flax capsule harvesting test bench

Technical parameters	Value	Units
Whole machine size (length× width× height)	1335×870×750	mm
Working width	570	mm
Rotational speed of roller shaft	0-139	rad/min
Length of comb tooth	140	mm
Clearance of comb tooth	4	mm
Power of centrifugal ventilator	3000	W
Pressure of centrifugal ventilator	1210-998	Pa
Air volume of centrifugal ventilator	6000-7640	m^3/h
Power of motor	2200	W
Transmission ratio	1:9	/

Dynamics analysis of main components

Analysis of the process of capsule being brushed

The comb-tooth flax capsule brush roller is mainly composed of active hexagonal disc AB (original actuator), driven hexagonal disc DC (actuator), connecting piece BC (actuator), frame AD, comb tooth frame, driven shaft, roller shaft and other structures, all of which also constitute a parallel four-bar mechanism (Fig. 3 - a, c). The comb tooth of the brush roller does parallel movement under the constraint of the parallel four-bar mechanism, the comb gap are designed for 4 mm, the comb teeth are designed with a certain angle to the horizontal direction (α=10°). The action direction of the parallel moved comb teeth on the plant is certain, the phenomenon of the plant winding roller is avoided. The motion tracks of the comb tooth frame, driven shaft and comb tooth of the parallel four-bar mechanism are S_1, S_2 and S_3 (Fig. 3 - b, c), they all move in circles (*Xu et al., 2021*). Take point A as the origin of coordinates and establish the coordinate system (Fig. 3 - c), the motion trajectory equation of the comb tooth tip as follows. This allows a better understanding of the working principle of the device and the movement of the capsule.

$$\begin{cases} x = \overline{BE}\cos\alpha + \overline{AB}\cos\theta + v_R t = \overline{BE}\cos\alpha + \overline{AB}\cos\omega t + v_R t \\ y = \overline{BE}\sin\alpha + \overline{AB}\sin\theta = \overline{BE}\sin\alpha + \overline{AB}\sin\omega t \end{cases} \quad (1)$$

Taking the derivative of equation (1) with respect to time, the velocity equation of the comb tooth can be obtained as follows.

$$\begin{cases} v_x = -\omega\overline{AB}\sin\omega t + v_R \\ v_y = \omega\overline{AB}\cos\omega t \end{cases} \quad (2)$$

Where:

α is the angle between the comb tooth and the horizontal direction; θ is the rotational angle of the brush roller (independent variable); ω is the uniform rotational speed of the brush roller, [rad/min]; V_R is the moving speed of the test bench relative to the plant, [m/s]; $\overline{AB}$ is the distance between the center of the shaft hole of the active hexagonal disc and the axis of the roller, [m]; $\overline{BE}$ is the length of the comb tooth, [m].

To do a stress analysis of the capsule during the brushing process (Fig. 3 - b), mg is the gravity of the capsule itself, F_N is the supporting force of the comb tooth, F_f is the friction of the comb teeth. The capsule is subjected to centripetal force in the +x region as shown in Formula (3), So the capsule is attached to the surface of the comb tooth; The capsule is not subjected to centripetal force in the -x region and rolls freely along the inclination angle of the comb teeth.

$$F_r = mg\sin\alpha + fmg\cos\alpha = m\frac{v_r^2}{r} \tag{3}$$

Where:

m is the mass of capsule, [kg]; *f* is the dynamic friction coefficient of comb teeth; v_r is the centripetal speed of the comb tooth, [m/s]; *r* is the distance between the comb tip and point A, [m].

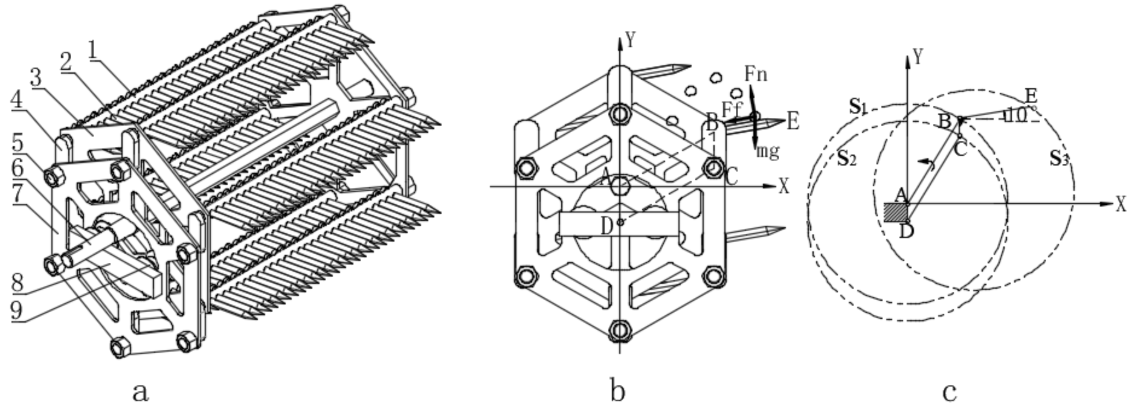

Fig. 3 - Structure diagram and motion trail diagram of parallel four-bar mechanism

1-Comb tooth rack; 2-Comb tooth; 3-Active hexagonal disc; 4-Connections; 5-Driven shaft; 6-Roller shaft; 7-Driven hexagonal disc; 8-Slot wheel carrier; 9-Slot wheel

Analysis of the process of capsule being collected

To do the following analysis according to the different situations in the collection process, the coordinate system was established with the centre of mass of the capsule as the origin. Fig. 4 - a shows that after the capsule is removed, it bounces up in the air between the brush device and the protective cover, the capsule is mainly affected by the wind force of the fan and its own gravity, the equilibrium equation is shown in equation (4); Fig. 4 - b shows the capsule falling on the surface of the comb teeth after being removed, the capsule is mainly affected by the centrifugal fan's wind force, its own gravity, the friction of the comb tooth, the support force of the comb tooth, the equilibrium equation is shown in equation (5); Fig. 4 - c shows the situation in which the capsule falls on the surface of the brush roller guard after being removed, the capsule is mainly affected by the wind force of fan, the gravity of the capsule itself, the friction of the protective cover, the support force of the protective cover, the equilibrium equation is shown in equation (6). In Fig. 4 -a, b, c, V represents the capsule motion velocity vector. According to the above stress analysis, the capsule in the air between the brush device and the protective cover has the least resistance, so it is the easiest to collect, the capsule on the surface of the protective cover is next, the capsule on the comb tooth surface of the brush device is slightly difficult to collect, and the capsule outside the protective cover cannot be collected because it is not in the air duct. These forces are an important basis for designing the structure and strength of the test bench.

$$\begin{cases} F_x = F_{AFx} + F_{FW} = ma_x \\ F_y = F_{AFy} + mg = ma_y \end{cases} \tag{4}$$

$$\begin{cases} F_x = F_{f1} + F_{AFx} + F_{FW} = ma_x \\ F_y = F_{f2} + F_{AFy} + F_1 = ma_y \\ F_z = F_{f3} + F_{AFz} = ma_z \end{cases} \tag{5}$$

$$\begin{cases} F_x = F_f + F_{AF} + F_{FW} = ma_x \\ F_y = F_1 + mg = ma_y \end{cases} \tag{6}$$

Where:

F_{AF} is the air resistance to the capsule, [N]; F_{FW} is the force of the centrifugal fan to the capsule, [N]; F_f is the frictional resistance to the contact surface of the capsule, [N]; F_1 is the support force on the contact surface of the capsule, [N]; *a* is the acceleration of the capsule, [m/s^2]; *m* is the mass of the capsule, kg; *x*, *y*, and *z* indicates the direction of the coordinate axis.

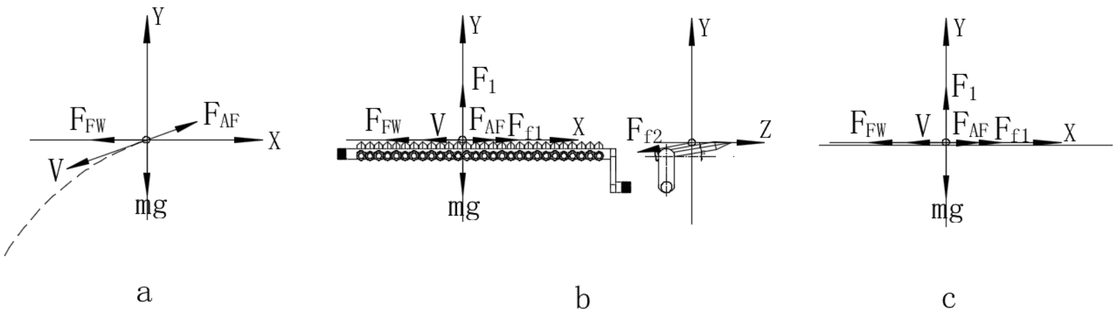

Fig. 4 - Schematic diagram of flax capsule collection process

Experiment design

Determination of experimental factors and its control methods

According to the bench test results of the comb-tooth flax capsule brush test bench (*Xu et al., 2021*), combined with the structure arrangement and working principle of comb-brush air-suction composite flax capsule harvesting test bench, the following four experimental factors were selected, comb tooth cross section shape *A*, brush roller rotational speed *B*, speed of the machine moves relative to the plant *C*, centrifugal fan air volume *D*, the experimental factors and levels are shown in Table 2. The shape of the comb tooth cross section is controlled by installing different the comb tooth with cross section shapes, the brush roller rotational speed by adjusting the motor speed to control, the speed of the machine moves relative to the plant and is controlled by adjusting the speed of the stepper motor on the guide rail, the air volume of the centrifugal fan is controlled by adjusting the size of the fan inlet.

Table 2

Experiment factors and levels

Levels	Shape of comb tooth cross section	Rotational speed of roller shaft	Relative speed of the machine	Air volume of centrifugal ventilator
	/	[rad/min]	[mm/s]	[m³/h]
	A	*B*	*C*	*D*
-1	rectangular	44	80	2000
0	circular	67	140	4000
1	diamond	90	200	6000

Determination of experimental index and its calculation methods

According to the bench test results of the comb-tooth flax capsule brush test bench (*Xu et al., 2021*), combined with the structure arrangement and working principle of comb-brush air-suction composite flax capsule harvesting test bench, the following four test indexes were selected, capsule removal rate is Y_1, capsule breaking rate is Y_2, capsule collection rate is Y_3, plant winding rate is Y_4. The test bench requires the plant winding rate as small as possible, and other test indicators as large as possible.

The calculation formula of each test index was shown in the following formula.

$$Y_1 = \frac{M - M_1}{M - M_2} \times 100 \tag{7}$$

$$Y_2 = \frac{M_3 - M_4}{M_3} \times 100 \tag{8}$$

$$Y_3 = \frac{M_3}{M - M_1} \times 100 \tag{9}$$

$$Y_4 = \frac{M_5}{M} \times 100 \tag{10}$$

Where:

M is the total weight of the flax plant before being brushed, [g]; M_1 is the weight of the flax plant after being brushed, [g]; M_2 is the weight of the flax plant after excluding all capsules, [g]; M_3 is the total weight of the capsules that are collected by the fan outlet, [g]; M_4 is the weight of the unbroken capsules that are collected by the fan outlet, [g]; M_5 is the weight of the flax plant wrapped around the brush roller, [g].

RESULTS AND ANALYSIS

Bench test

Experiment scheme and results

Orthogonal experiments with four factors and three levels were designed according to the orthogonal table with $L^9(3^4)$ to study the significance of the influence of each experimental factor to the each experimental index. A total of 9 groups of experiments were conducted, and each group of experiments was repeated three times to take the average value, each test index was calculated according to formula (7)~(10) for each test. The factors and levels of the orthogonal test were shown in Table 2, and the orthogonal test scheme and results were shown in Table 3, and Table 3 was made based on Table 2.

Table 3

Experiment scheme and results

Test number	Levels of experiment factors				Experiment index			
	A	*B*	*C*	*D*	Y_1[%]	Y_2[%]	Y_3[%]	Y_4[%]
1	1	1	1	1	98.19	97.42	94.45	1.79
2	1	0	0	0	97.37	97.25	82.87	4.21
3	1	-1	-1	-1	96.30	95.57	30.13	0.36
4	0	1	0	-1	94.39	96.16	28.73	0.00
5	0	0	-1	1	96.92	97.53	95.63	0.38
6	0	-1	1	0	97.62	98.06	89.63	0.17
7	-1	1	-1	0	97.68	98.15	90.30	0.93
8	-1	0	1	-1	96.45	96.23	30.05	0.00
9	-1	-1	0	1	95.85	97.99	94.67	0.00

Experiment data analysis

According to the range analysis results (Table 4), the optimal experimental factors combinations of capsule removal rate, breaking rate, collection rate and plant winding rate respectively were $A_1B_0C_1D_0$, $A_{-1}B_1C_1D_0$, $A_{-1}B_{-1}C_{-1}D_1$ and $A_{-1}B_{-1}C_{-1}D_{-1}$. The effects of various factors on the capsule removal rate, breaking rate, collection rate and plant winding rate respectively were in the following order: *D>C>A>B*, *D>A>B>C*, *D>C>A>B*, *A>D>B>C*.

Table 4

Range analysis of orthogonal experiment

Analysis item	Y_1[%], Capsule removal rate				Y_2[%], Capsule shell breaking rate			
	A	*B*	*C*	*D*	*A*	*B*	*C*	*D*
K_1	97.28	96.75	97.42	96.99	96.75	97.24	97.24	97.65
K_0	96.31	96.92	95.87	97.55	97.25	97.01	97.13	97.82
K_{-1}	96.66	96.59	96.97	95.72	97.46	97.21	97.08	95.87
Range	0.97	0.32	1.54	1.84	0.71	0.24	0.15	1.84
Optimal solution	$A_1B_0C_1D_0$				$A_{-1}B_1C_1D_0$			
P&S factors	*D>C>A>B*				*D>A>B>C*			
K_1	69.15	71.16	71.38	94.92	2.12	0.91	0.66	0.73
K_0	71.33	69.52	68.75	87.60	0.18	1.53	1.77	1.77
K_{-1}	71.68	71.48	72.02	29.64	0.30	0.17	0.56	0.12
Range	2.52	1.96	3.26	65.28	1.94	1.36	1.21	1.65
Optimal solution	$A_{-1}B_{-1}C_{-1}D_1$				$A_{-1}B_{-1}C_{-1}D_{-1}$			
P&S factors	*D>C>A>B*				*A>D>B>C*			

Note: K_i is the average of the corresponding results when the level number on any column is i (i=1,0,-1).

Because each index optimal working condition was different, the comprehensive weighted scoring method was adopted to give consideration to the gains and losses of each index. According to the experience and practical requirements, since the experiment bench mainly solves the problem of plant winding and capsule collection, the capsule collection rate was related to the work efficiency of the test bench, it is considered that capsule removal rate, collection rate and plant winding rate were equally important, and the weights were 0.3 respectively. Since the collected capsules have to go through the subsequent breaking and threshing process regardless of the breaking degree, so the breaking rate was not the most important in this experiment, and the weight was given to 0.1. According to the comprehensive weighted scoring value, the range analysis of the test results was carried out (Table 5). It showed the optimal working parameters combined of the test bench as follows: the shape of the comb tooth cross section was rectangular, the rotational speed of the comb roller was 44 rad/min, the speed of machine travel relative to the plant was 80 mm/s, the air volume of the fan was 6000 m^3/h.

Table 5

Comprehensive weighted score range analysis results

Analysis item	Experiment factors			
	A	*B*	*C*	*D*
K_1	58.97	59.83	60.17	67.12
K_0	59.96	59.17	58.57	64.79
K_{-1}	60.15	60.09	60.24	47.17
Optimal solution	$A_{-1}B_{-1}C_{-1}D_1$			

Note: K_i is the average of the corresponding results when the level number on any column is i (i=1,0,-1).

According to the results of the variance analysis (0), none of the experiment parameters had significant effect on the capsule removal rate.

Table 6

Variance analysis of orthogonal experiment

Index	Variance Sources	*DF*	*Anova SS*	*Mean Square*	*F* value	*P* value
Y_1[%] Capsule removal rate	*A*	2	4.39	2.20	0.60	0.5610
	B	2	0.47	0.24	0.06	0.9380
	C	2	11.42	5.71	1.55	0.2386
	D	2	16.02	8.01	2.18	0.1422
	Model	8	32.31	4.04	1.10	0.4084
	Error	18	66.20	3.68	R^2=0.328 Coeff var=1.98	
	Sum	26	98.51			
Y_2[%] Capsule shell breaking rate	*A*	2	2.39	1.19	4.72	0.0225
	B	2	0.30	0.15	0.59	0.5651
	C	2	0.11	0.06	0.22	0.8026
	D	2	18.46	9.23	36.56	<0.0001
	Model	8	21.26	2.66	10.52	<0.0001
	Error	18	4.55	0.25	R^2=0.82 Coeff var=0.52	
	Sum	26	25.81			
Y_3[%] Capsule collection rate	*A*	2	33.69	16.85	0.81	0.4613
	B	2	19.96	9.98	0.48	0.6273
	C	2	53.76	26.88	1.29	0.2998
	D	2	23025.30	11512.65	551.99	<0.0001
	Model	8	23132.74	2891.59	138.64	<0.0001
	Error	18	375.41	20.86	R^2=0.98 Coeff var=6.46	
	Sum	26	23508.15			

Index	Variance Sources	*DF*	*Anova SS*	*Mean Square*	*F* value	*P* value
Y_4[%] Flax plants winding rate	***A***	2	21.19	10.60	3.71	0.0449
	B	2	8.31	4.15	1.45	0.2602
	C	2	3.87	1.93	0.68	0.5212
	D	2	12.54	6.26	2.19	0.1406
	Model	8	45.90	5.74	2.01	0.1049
	Error	18	51.48	2.90	R^2=0.47 Coeff var=193.96	
	Sum	26	97.38			

Note: P<0.05(significant,); P<0.01(highly significant,**)*

According to the results of the capsule brushing test in the early stage (*Xu et al., 2021*), the optimal clearance of comb teeth selected in this test was 4 mm, when different shapes of comb teeth cross section are installed under this clearance, the capsule can be brushed off and the capsule removal rate is very high. The effects of comb tooth cross section shape, centrifugal fan air volume and other factors on capsule breaking rate respectively were significant, extremely significant and insignificant. This is because the capsule is in direct contact with the comb tooth, the impact force between the capsule and the fan blade and the collection box is also different for the different wind force of the centrifugal fan. Therefore, the degree of capsule breaking is different due to the different shapes of the comb tooth cross section and different fan air volume. The influence of the air volume of centrifugal ventilator and other factors on capsule collection rate respectively was extremely significant and insignificant, this is because the capsule is mainly collected by the fan, so the greater the air volume of the fan, the better the collection effect of the capsule. The effects of comb tooth cross section shape and other factors on plant winding rate respectively were significant and insignificant. This is due to the direct contact between the plant and the comb teeth, the damage degree of the plant is different with different shapes of the comb teeth cross section, this results in the different plant winding rates.

Experimental Verification

Under the conditions of the optimal experiment parameters combination, the test bench was tested and verified, and the test verification results are shown in 0. The capsule removal rate was 96.45%, the capsule breaking rate was 98.79%, the capsule collection rate was 95.65%, and the plant winding rate was 2.52%. The results indicating that the combing, collection and anti-entanglement effects of the test bench were better.

Table 7

Experiment results of the test bench verification test

Test index	Test number			Average value
	1	**2**	**3**	
Y_1[%], Capsule removal rate	98.13	94.75	96.48	96.45
Y_2[%], Capsule shell breaking rate	98.76	99.48	98.12	98.79
Y_3[%], Capsule collection rate	93.46	97.15	96.35	95.65
Y_4[%], Flax plants winding rate	2.72	2.86	1.99	2.52

CONCLUSIONS

In this paper, the comb-brush air-suction composite flax capsule harvesting test bench was designed, on the basis of the harvesting methods of obtaining flax's capsule firstly and then breaking and threshing it. Single-factor tests and multi-factor orthogonal tests of each test factor were conducted to analyse the significant differences in the effects of each test factor on each test index and the order of effects, the results of the orthogonal test showed that the combing, collecting and anti-entanglement effects of the test bench were good. It provides a feasible solution to solve the problem of plant winding thresher roller in the process of mechanized flax harvesting and avoid the phenomenon of flax broken straw blocking the sieve hole. The test bench has a compact structure, easy to install and disassemble, and reasonable transmission.

The flax capsule material collected by the test bench is semi-threshing material, with little straw in the material, which is conducive to subsequent shell breaking and threshing of the capsule. It provides the basis of components and theoretical reference for the innovative design of flax harvester. It lays a theoretical basis and data basis for the design of comb-brush air-suction composite flax capsule harvesting device. So there are great prospects for application.

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