Research and application of twin-screw expeller for cold pressing of de-hulled rapeseed

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Abstract

In order to solve the technical problems of cold pressing of de-hulled double-low rapeseed, a new twin-screw expeller with a principle of combination of joggling and non-joggling was designed and manufactured. The pressing chamber had characteristics of multiple-stage compression and relaxation and a thin layer of materials when pressing. Theoretical compressing ratio of the twin-screw expeller is 23.0, and ratio of length and diameter of pressing chamber is 11.5 with a pressing time of 180 seconds. In the twin-screw expeller, materials could be clear intensely so that the problem of de-hulled rapeseed feeding was solved. The twin-screw expeller was applied to cold pressing of de-hulled rapeseed successfully. The oil content of cold pressing cake is reduced to about 15%. Cold pressing oil approaches the standard of the third grade rapeseed pressing oil (Chinese national standard, GB1536-2004). Cold pressing cake temperature is lower than 70°C which assures good quality of oil and cake. Twin-screw expeller is suitable for pressing de-hulled rapeseed with obvious quality improvement of rapeseed oil and reduction of energy consumption, which can increase processing value of double-low rapeseed.

Key words: twin-screw expeller, double-low rapeseed, de-hulled, cold pressing, equipment

Introduction

At present, pre-pressing process is mainly used to process double-low rapeseed in the world, which is carried out with hulled rapeseed at high temperature for long time. As a result, the quality of crude oil is not good, for example, dark colour, rich in impurities, difficult to refine (Elizabeth et al., 1991). The cake is contains low protein, with dark colour and bad taste. Moreover, protein is over-disnatured, and effective amino acids are badly destroyed, which affects the utilization efficiency of protein (Zheng, 2001). Study on dehulling and cold pressing technology is gaining increase interesting all over the world. By using dehulling and cold pressing technique, perfect cold pressing oil could be produced by double-low rapeseed, and refine process is simplified (Huang, 2002). Meanwhile pollution by chemical reagents is avoided, and functional components such as VE can be retained in oil. Thus, this is an ideal method to provide natural green food. With this process, the protein content in cake is improved, and effective amino acids are not destroyed under lower temperature. The nutritional value of crude protein is also improved. At the same time, the process of flaking and cooking can be skipped, which obviously reduces energy consumption (Ragnar, 1992; Rasehorn et al., 2000).

Cooperating with University - Gesamthochschule Essen, Cimbria Sket GmbH had made key equipment used for dehulling and cold pressing process in 2000. Rapeseed dehulling and cold pressing pilot-plant has been built, cold pressing oil that is organic can be produced. The price of organic oil is 3~5 times more compared to rapeseed salad oil (Xin, 2005). Equipments used to dehull and separate rapeseed have been made at home (Zhang, 2004; Huang et al., 2000). And it is designed with many principles. Study on cold pressing equipment has just started (Li et al., 2004). However, the equipment used to cold press and produce oil with high efficiency should be exploited and applied widely. In this work, the study on the twin-screw expeller and its application is reported.

1 Problems of single-screw expeller

Experiments about cold processing of de-hulled rapeseed were started with the traditional single-screw expeller including ZX10, ZX18, ZY24. The result revealed that the feedstock was difficult to push in the chamber, producing shapeless cake and a little oil or even no oil. The possible reasons were assumed as following. Firstly, oil content in de-hulled rapeseed kernel amounted to about 45%, and the crude fiber reduced vastly to 3%~5%. So the properties of feedstock such as density, frictional factor, elastic modulus, etc. were obviously different from non de-hulled rapeseed oil, especially the friction among feedstock particles, or among feedstock particle and pressing cage inter surface reduced vastly. So it is difficult to deliver the feedstock in the chamber, and the pressure in the whole pressing progress was difficult to build up. Secondly, in cold pressing, the de-hulled rapeseed was not pretreated by flaking and cooking, and the feedstock cells were basally integrated. The affinity between protein and fat was still strong. So, higher pressure was needed to press the oil out. Traditional single-screw expeller was difficult to realize cold pressing of de-hulled rapeseed.

The structure of the single-screw expeller made in China was evaluated (Zhu & Shi, 1991). Many problems were detected, such as too small ratio of length and diameter of pressing chamber, a little low total theoretical compressing ratio, too short length covered by feedstock delivering screw, low delivering ability, and so on. The chamber of present single-screw expeller was not suitable for cold pressing. In order to realize the cold pressing for de-hulled rapeseed, it is necessary to

improve the pushing ability of the feedstock delivering screw, strengthen the pressure and prolong pressing time.

2 Research about twin-screw cold pressing expeller

2.1 Design

New twin-screw expeller for cold pressing was designed to solve the above mentioned problems of single-screw expeller. And the design was as following.

(1) Twin-screw improved the pushing ability vastly, and the problem that de-hulled rapeseed was easy to slip in chamber was radically solved. Combination of joggling and non-joggling was designed in twin-screw expeller (Figure 1). Left and right worm of first screw segment joggled mutually. That was to say the screw bridge of one piece of screw inserted into the screw groove of another, and there was certain space around. Its ability to push the feeding was strong. The exterior diameter of both worms in the second screw was tangency, which was non-joggling. It not only has strong ability to push feedstock along axis, but also its structure fits to multiple-stage compression and relaxation and a thin layer of materials when pressing. This design had the characters of strong ability to push the feedstock in axis direction, and convenient regulation of the pressure in chamber and compression ratio of worm and pressing loop.

(2) Pressing cage and worm shaft were the heart of the expeller. However there were faults in single-screw expeller about its small ratio of length and diameter of pressing chamber and a little low total theoretical compressing ratio. To improve these faults, some changes in design principle and its structure had been made (Figure1). The total length of worm shaft was lengthened by the form of composition of multiple segment pressing screw and pressing loop. When many taper pressing loops were inserted into the space between two screws, multiple-stages compression and relaxation could be realized. Meantime, the ratio of length and diameter of pressing chamber and total theoretical compressing ratio were improved. In the main pressing segment, with the root diameter of pressing screw increasing gradually along the axis in vertical direction, the depth from the top of pressing screw teeth to the root reduced gradually. So a thin layer of materials when pressing was realized and the distance to exclude oil was shortened, which benefited improving the oil extraction rate.

(3) The two worm shafts circumvolved in different directions. The circumvolving direction was anti-direction from inside to outside which was decided by power beared and the oil excluding manner. When working, suspending worm shafts circumvolve centered automatically, which was also required when no-load.

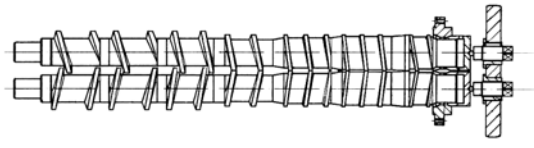
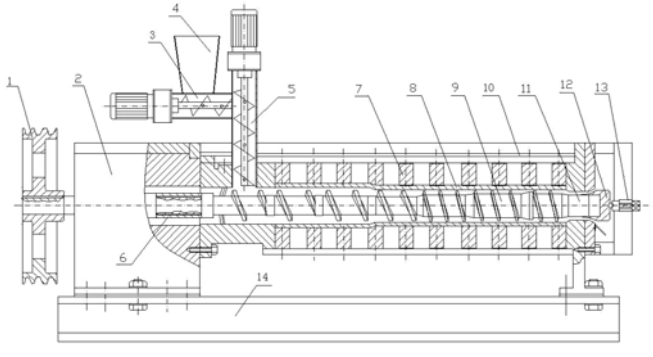


Fig.1 Sketch of twin-screw expeller with combination of joggling and non-joggling

2.2 Equipment structure

The module of twin-screw expeller was designed and manufactured according to the design mentioned above. Laboratory test of cold press for de-hulled rapeseed kernel was carried out and gained elementary success. Based on this, the equipment was improved and modified mainly about its delivering part, pressing chamber and pressure structure passing part. SSYZ50 twin-screw expeller was designed and manufactured successfully. The simply structure diagram was shown as figure 2.



1 Strap tray 2 Gear case 3 Level screw conveyor 4 Hopper 5 Vertical screw conveyor 6 Jointer 7 Pressing plate 8 Bar withstanding device 13 Accommodated mandril 14 Framework 9 Worm shaft 10 Pull rod 11 Outlet tray 12 Cake

Fig.2 Structural diagram of SSYZ50 twin-screw expeller

The main technical parameters of SSYZ50 twin-screw expeller were shown in table 1.

Table 1 Specifications of SSYZ50 twin-screw expeller

Item	Value
Total length of worm shaft (mm)	1800.0
Inner diameter of first stair pressing cage (mm)	160.5
Exterior diameter of first stair worm (mm)	154.0
Inner diameter of second stair pressing cage (mm)	140.5
Exterior diameter of second stair worm (mm)	136.0
Rotate speed of worm shaft (r/min)	10~18
Compressing ratio	23.0:1
Ratio of length and diameter	11.5:1
Press time (s)	180.0
Yield (T/d)	40~50
Power of principal electromotor (KW)	37~55
Externality dimension (length × width × height)mm	3900 × 2500 × 1800

2.3 Characteristics of this equipment

Compared with the traditional single-screw expeller, SSYZ50 twin-screw expeller had characteristics as following:

(1) Two screws delivered pressing oil in different directions in the same pressing cage, which was special structure. In the first segment of pressing chamber, left and right screws joggled mutually, and the feedstock between two screw grooves was half obturated. After feedstock particles entered pressing cage, they got the friction between screw thread and inner surface of pressing cage and friction among themselves. The moving state of feeding particles could be analyzed as circumvolving movement with axis and movement in axis direction. The main movement was circumvolving movement with axis, because the feedstock fraction was low. When feedstock moved in different directions to the joggling place, it got the function of press and friction. The circumvolving movement with the axis was destroyed, and the movement in axis direction increased obviously. So pushing function in axis direction with strong force came out. Screw groove was divided into small separated chambers with C shape in the joggling place, so feedstock was pushed ahead by the screw along the C chambers, and it was pressed lightly. During the second segment in the pressing chamber, exterior diameter of left and right screws was in tangency, and the two screw grooves communicated. Feedstock mainly went ahead with the screw, however, the function of mutual press and friction was also produced in tangency place. So the problems such as weak friction among de-hulled rapeseed kernels and feedstock r were ultimately solved.

(2) As showed in table 1, the design of twin-screw expeller provided high compressing ratio which could reach 23.0 theoretically, strong pressure in vertical direction which gave feedstock huge chemical pressure, high length and diameter ratio that reached 11.5:1, and prolonged the press time to 180s which made pressing drastically. Meanwhile thin layer of materials when pressing in long distance was realized and the distance of oil flow was shortened, which provided abundant time to press oil at high pressure. Actually the time to press oil at high pressure could reach more than 80s, so the yield ratio of pressing oil was improved. However, present ZX10 and ZX18 single-screw expeller had the ratios of length and diameter of press chamber of 6.3 and 6.72, respectively. The later had the theoretically compressing ratio 13.2, pressing time of 150s (Zhu & Shi, 1991)

3 The production and utilization state of twin-screw expeller

In July of 2004, SSYZ50 twin-screw expeller was successfully used in the new producing line of de-hulling, cold pressing, and expansion which was installed by Zhongpai Food and Oil Co. Ltd. in Wuhan, China. The production and utilization was as following.

The material of rapeseed was cleaned and dried, with water content about 8%. YTTP75 dehuller, which was designed and manufactured by Oil Crops Research Institute of Chinese Academy of Agricultural Sciences, was used to dehull and separate hull and kernel (Dehulling ratio was more than 95%). Rapeseed kernel with rate of 3-6% hull was gained. Rapeseed kernel was put into twin-screw expeller for cold pressing.

Table 2 The application results of twin-screw expeller for cold pressing of de-hulled rapeseed

Serial number	Water content of rapeseed kennerl(%)	Residual oil content of cold–pressed cake (%,dry matter basis)	Water content of cold–pressed cake(%)	Temperature of excluding cake(°C)
1	7.9	15.08	5.7	51
2	6.1	14.72	4.6	58
3	8.5	15.60	5.9	56
4	6.4	14.35	4.8	48
5	7.1	16.35	5.3	63
Average	7.2	15.22	5.3	55

Results were shown in table 2. Residual oil content of cold pressed cake was about 15%, which corresponded to residual oil content of pre-pressed cake. Better oil extraction rate was gained. Water content in cold pressed cake was 4-6%, which

descended by 1-2% compared with material of de-hulled rapeseed. Cold pressed cake came out at the temperature of about 55°C that was lower than 70°C, which fulfilled the requirement of cold pressing process. In the producing process, the equipment worked well, and the properties of the machine were stable. Disposal ability amounted to 45t/d.

The quality of cold pressing oil was tested by Quality Inspection and Test Center for Oilseeds and Products, Ministry of Agriculture, PRC. Results showed that some quality indexes such as colour and lustre, acidity were better than crude oil from pre-pressing process (Table 3). Its quality is better than the standard of the fourth grade rapeseed pressing Oil, almost as the standard of the third grade rapeseed pressing oil (Chinese national standard, GB1536-2004). Following refining process could be reduced. Contact with organic chemical reagent was avoided, so natural green production was gained.

Table 3 The quality of cold pressing double-low rapeseed oil

Index	The third grade rapeseed pressing oil	Cold pressing rapeseed oil
Colour and luster (Trough thickness 25.4mm)	≤Y35 R4.0	Y35 R4.0
Odor and taste	Having the inherent flavor and taste of rapeseed oil, no peculiar smell	Having the inherent flavor and taste of rapeseed oil, no peculiar smell
Acidity(mg KOH·g-1)	≤1.0	1.1
Moisture content and volatile materials(%)	≤0.10	0.04
Infusbility impurity(%)	≤0.05	0.01
Impurity(%)	≤0.10	0.01
Peroxide value(mmol/kg)	≤6.0	3.2
Heating test(280°C)	The colour allow to be deepen and not to be darken. Trace matter allow to be separate out.	The colour become deepen. No matter is separate out.
Soap content(%)	≤0.03	0.01

4 Conclusions

(1) In order to realize cold pressing of de-hulled double-low rapeseed, a twin-screw expeller with a principle of combination of joggling and non-joggling was designed. In the expeller, feedstock could be cleared away automatically, so the problem that de-hulled rapeseed feedstock was difficult to be delivered was solved. In the pressing chamber, multiple-stage compression and relaxation and a thin layer of materials when pressing were applied. The total theoretical compressing ratio of the twin-screw expeller and ratio of length and diameter of pressing chamber were improved obviously. Pressing time was prolonged. SSYZ50 twin-screw expeller was designed according these theories. The total theoretical compressing ratio of the twin-screw expeller reached 23.0, and the ratio of length and diameter of pressing chamber reached 11.5. Meanwhile pressing time prolonged to 180s.

(2) SSYZ50 twin-screw expeller used in oil processing corporations successfully. Results revealed that oil content of cold pressing cake from de-hulled rapeseed was about15%. Better yield ratio of cold pressing oil was gained which approached the standard of the third grade rapeseed pressing oil (Chinese national standard, GB1536-2004), and could be treated as natural green food. Cold pressed cake came out at the temperature that was lower than 70°C, which fulfilled the requirement of cold pressing process.

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