Abstract

With the increasing consumer demand, the mechanized shrimp productions become more and more popular for its high efficiency and much less bacterial infection. In particular, removal of shell and vein plays an important role to guarantee clean production in the shrimp processing. There are several kinds of machines which can achieve the required function worldwide up to now. Among these machines, the machine featured with a rotary plate has significant advantages if compared with others. Thus the structure and the development process about it were summarized in this paper. Through the summary, the advances of this machine were outlined in detail, and the future research direction of the industry of shrimp peeling machine was also indicated, that is, the mechanical structure need to be optimized and simplified. Meanwhile, if advanced electric automatic control system introduced, the labor occupation would be significantly reduced, and the production quality, productivity and efficiency accordingly be enhanced.

Key words: Shrimp peeling machine, Review, Deveining station, Separating station

1. Introduction

Shrimp is popular for its good taste and high nutritional value. In 1998, the world's shrimp farmers produced approximately 850,000 metric tons of wholseshrimp (FAO, 1999). Between 2002 and 2008, global shrimp production has increased by 34% (FAO, 2009). From 2009 to 2012, there was a fluctuation in the shrimp yield; in spite of this, shrimp continued to be the largest single commodity in value terms; in 2012, the shrimp market began with positive notes in demand and price trends (FAO, 2012). As can be seen, shrimp production market is large and has a good prospect. But the shrimp is covered with a shell and contains an inedible sand vein near its back. Although occasionally it may be desirable to leave the meat in the shell (known as EZpeel style), it is required to remove the shrimp meat from the shell generally, and the vein must be removed before eating. As a common sense, hand removal of veins and hand shelling are tedious and inefficient. More importantly, serious bacterial infection is easy to be caused (Zhou, 2010), and it is most undesirable when large numbers of shrimps need to be processed instantly. Therefore, it is necessary to develop a machine which can be used to remove the meat from the shell and the vein from the shrimp.

So far numerous efforts have been dedicated to shrimp peeling machine research and development. There are two kinds of shrimp peeling machine which can represent the highest level of this industry sector in the world. One is the machine featured with a rotary plate (Machine A) and the other is the machine mainly based on roll shafts (Machine B) (Qiu, et al., 1993). Machine B removes the meat from the shell by extrusion between the rollers (Lapeyre, et al., 1992). It can peel any size from 10 to 200 shrimps per pound whether they are headless or not, however the shrimp must be refrigerated before the process. For its productivity, a single machine is capable of peeling approximately 400-450 kg/hr. Moreover, this machine can feed continuously and automatically. However, this machine cannot remove the vein from the shrimp and can only yield one production style called tail-off round. By contrast, Machine A can peel any size from 10 to 90 shrimps per pound, because the mechanism can be adjusted automatically according to the size of each individual shrimp. What is more, a single machine of this kind can process 4300 shrimps per hour. Also, as shown in Fig. 1, this kind of machine can process many styles of shrimp production including tail-on round, tail-on...
butterfly split, tail-on western style, tail-off round and EZ peel. The change from one style to another can be done in seconds and no tools needed. Also this kind of machine can peel warm water species, pond-raised or wild, freshwater shrimp regardless of fresh or previously frozen.

As mentioned above, Machine A has many advantages over Machine B, thus it can represent the current highest technical level of the shrimp peeling machine. Therefore, the objective of this paper is to summarize the structure and the development process of this machine mainly according to granted patents, and to indicate the future research direction of shrimp peeling industry.

2. Summary of the structure and development process of Machine A

2.1. The main structure of the machine

U.S. Pat. No. 2784450 was the first granted patent of this kind of machine (Jonsson, 1957). And U.S. Pat. No. 2850761 was a divisional of the application U.S. Pat. No. 2784450 (Jonsson, 1958). Their inventor is Gregor Jonsson who laid the foundation for this machine. In these two patents, the main structure was disclosed as shown in Fig. 2. The machine included a conveyor cooperated by a receiver for conveying the shrimp from a container to a carrier. After that was the carrier comprising six circularly arranged clamp assemblies for transferring the shrimp through the work stations one by one. The machine also included a plurality of work stations including centering station, cutting and deveining station, separating station and discharge station. The power to drive all these stations, the conveyor, and the clamp assemblies was provided by an electric motor and was transferred by a set of complex drive mechanism.

The working process of peeling shrimp described in these two patents (Jonsson, 1957; Jonsson, 1958) was as follows. The shrimp was loaded by hand from a container into a receiver with the tails positioned away from the operator. The conveyor was intermittently operable and was stationary while the shrimps were dropped from the receiver onto it. Once the shrimp from the conveyor was clamped in the clamp assembly, the clamp assembly would take the shrimp through work stations one by one. First of all, the clamp assembly was rotated past a straightener to align the shrimp with the space between the open clamps, and passed by two grooved rollers to further centralize the shrimp and press down the shrimp against the back-up plate. Next was the cutting and deveining station where a rotary cutting blade cut the shrimp shell and the meat body along the longitudinal axis of the shrimp to expose the meat and pull out the sand.
vein. Continuous rotation of the carrier moved the shrimp past a roller which pressed the shrimp toward the back-up plate to pull the meat away from the shell partly. Following that was the separating station where a plurality of spikes reciprocated. The spikes, which gripped the shrimp meat, cooperated with the revolving clamp, which gripped the shrimp shell, to separate the shrimp meat from the shell. Following that, the spikes were retracted from the meat, and the meat was transported to a collection container while the shell was transported to the discharge station, where the shell was released from the clamp assembly and passed into a discharge container.

2.2. Development process of critical components

2.2.1. The conveyor

The initial conveyor was intermittently operable and was stationary while the shrimps were dropped from the receiver into it (Jonsson, 1957; Jonsson, 1958). After that, as shown in Fig. 3, a modification was made on the driving system of the conveyor to make the receiver needless and simplify manual loading of the shrimp onto the conveyor (Jonsson, 1964a; Jonsson, 1964b). Further, a new driving system of the conveyor named Geneva drive mechanism was disclosed (Jonsson, 1971; Jonsson, 1973). But in order to make an operator operate more easily, the conveyor was modified to travel constantly instead of intermittently (Betts, 1988).

In aforementioned patents, the feed conveyor was vertically aligned with longitudinal axis of the clamp assembly, and the procedure of dropping off a shrimp from the feed conveyor was synchronized to the clamp assembly by the mechanical transmission. A new feed system was provided later, in which the feed conveyor was longitudinally aligned with longitudinal axis of the clamp assembly and the procedure of dropping off a shrimp from the feed conveyor was synchronized to the clamp assembly by automatically changing the speed of the motor which drove the conveyor (Keith, 1994; Keith, 1996). This kind of automated feed system made sure that the shrimp was positioned properly and increased the processing speed. In addition, an improved tray (Fig. 4) was disclosed, which had a stripe located contiguous to one end of the tray that allowed an operator to visually orient a shrimp by locating the first segment of the shrimp in the tray relative to the stripe. Further, a detent was disposed atop the stripe and permitted an operator to further tactilely orient the shrimp by moving the shrimp along the tray length until the detent engaged the shrimp segment (Jonas, 1995).

2.2.2. The carrier

At the very beginning, the carrier comprised six circularly arranged clamp assemblies, and the clamp assembly comprised two components, one of which gripped the shrimp body while the remaining component gripped the shrimp tail. Also, there was a back-up plate to support the shrimp (Jonsson, 1957; Jonsson, 1958). To support the shrimp better, especially the tail part, a tail deflecting element was added (Fig. 5) (Jonsson, 1964a; Jonsson, 1964b). Further, as shown in Fig. 6, an improvement of the supporting structure in the clamp was made. The new structure combined the back-up plate with the tail deflecting element, and had a groove longitudinally for allowing the blade to cut the shrimp lengthwise and entirely without damaging the blade (Betts, 1983). Meanwhile, the disjointing clamp was added in the clamp, and it would be described later.
2.2.3. The disjointing station

There was no disjointing station originally, and the machine could only remove the shell and the tail together (Jonsson, 1957; Jonsson, 1958). But when the tail-on style is needed, the tail should not be torn away from the meat while the shell is removed. To achieve this, a disjointing clamp and a disjointing station used to drive the disjointing clamp were given. The disjointing clamp had only one jaw with pins (Fig.7). In the disjointing station, the tail and the shell of the main body portion were separated when the disjointing clamp was driven to move away from the tail clamp (Jonsson, 1964a; Jonsson, 1964b). However, in order to get a better separation, a new disjointing clamp (Fig. 8) which had two jaws with pins was brought in. The tail and the shell of the main body portion were separated when the two jaws were driven to separate in the disjointing station (Jonsson, 1965; Jonsson, 1966a). Further, a self-adjusting tail breaker means to automatically accommodate for different size shrimps was disclosed (Betts and Keith, 1985). In aforementioned patents, the machine could allow either the process wherein the tail and the entire shell was removed or the process wherein the tail and the first shell section were remained on the meat. However, an apparatus which allowed both processes was provided, and the change from one process to the other was easy to be done (Betts, et al., 1988).
2.2.4. The cutting station

At the very start, a weight was given to hold the blade in engagement with the back of the shrimp as it was carried past the blade, and a limit shop was provided for preventing the blade from cutting the shrimp too deeply (Jonsson, 1957; Jonsson, 1958). After that, a construction to slit the body of the shrimp longitudinally to any desired depth and to avoid the tail from cutting as well was provided (Jonsson, 1964a; Jonsson, 1964b). Further, a cam means (Fig. 9), which was used to decide where the blade entered a shrimp, was provided (Jonsson, 1971; Jonsson, 1973). In aforementioned patents, the cutting depth relative to the front of the shrimp instead of the back of the shrimp was adjustable. So a guide and cutting assembly was disclosed to selectively determine the cutting depth relative to the back of the shrimp (Keith, 1984).

The previous mechanism, for adjusting the location where a rotary blade entered a shrimp by the cam means, suffered from three disadvantages. First, it was not easy for an operator to remember how much he had adjusted. Second, the adjustment system was too difficult and tedious to operate. Third, for “tail-off” shrimp, the cam still rotated unnecessarily. To overcome above disadvantages, a cam means was provided for easily adjusting the position where the cutting blade entered the shrimp, and taking into account whether the shrimp was to be processed as “tail-off” or “tail-on” (Betts, 1991).

In the aforementioned patents, the cutting depth was adjusted by the cam means. However, an adjusting apparatus was put forward which adjusted the cutting depth relative to the front of the shrimp by using a plurality of different width shims (Pershinske, 1991). But this kind of means had no obvious advantages over the cam means, so it was not mentioned later. After that, a new structure was given to adjust and segment the position where the shrimp cutting blade entered the shrimp. The special point of this structure was that the position where the cutting blade entered a
shrimp could be adjusted more precisely (Keith, 2003).

2.2.5. The deveining station

The machine had no independent deveining station initially, and the cutting blade in the cutting station did the deveining meanwhile (Jonsson, 1957; Jonsson, 1958). Following that, a dependent deveining station was added where a fixed brush assembly served to sweep the vein from the shrimp meat as shown in Fig. 10 (Jonsson, 1965; Jonsson, 1966a). Further, a swingable deveining brush was brought into suit different sizes of shrimp (Jonsson, 1971; Jonsson, 1973). By this means, uniform brush depth can be achieved regardless of the size of the shrimp. As shown in Fig. 11, a dual brush deveining assembly was given later (Keith, 1994; Keith, 1996). In this assembly, one of the brushes served to clean another which did the deveining mainly. After that, an improved deveining brush (Fig. 12) was provided which had an apex to enter the shrimp to the deepest degree (Keith, 2002). The new kind of brush can be easily mounted and removed by an operator when it was necessary.

Fig. 10 The brush assembly (Jonsson, 1965; Jonsson, 1966a)

Fig. 11 The dual brush deveining assembly (Keith, 1994; Keith, 1996)

Fig. 12 The deveining brush (Keith, 2002)

2.2.6. The separating station

The initial separating station comprised a plurality of spikes which reciprocated vertically (Jonsson, 1957; Jonsson, 1958). However, it was found that a better separating result can be achieved if the spikes reciprocated circumferentially (Jonsson, 1966b; Jonsson, 1966c). As shown in Fig. 13, the shrimp meat held by the spikes was moved ahead slightly relative to the shell held by the clamp, and then pulled backwards to separate the body from the shell. Following that, a new separating station was disclosed. The spikes also reciprocated circumferentially, but an easier driving mechanism
of the spikes was provided (Jonsson, 1971; Jonsson, 1973).

In aforementioned patents, the meat separator spikes were straight, and the spikes engaged the shrimp meat at nearly a right angle to the carrier direction of motion, and tore the meat away at the beginning of the engagement. This affected the appearance of the shrimp meat, and cannot assure consistent separation of meat and shell. To overcome these disadvantages, an improved spike (Fig. 14) was brought in, which included an elongated shaft and a tip portion, wherein the tip portion was disposed at an angle from the shaft portion and pointed in a direction generally opposite to the direction of shrimp transfer by the carrier (Betts, 1983).

To make the cut of the shrimp meat smooth and clean, a new shrimp meat removal device (Fig.15) was given later (Keith, 1994; Keith, 1996). There were two groups of spikes and the spikes rotated around the center point O as shown in Fig. 15. After that, a new separating assembly was disclosed which comprising a fork with only one spike (Dancy and Keith, 2011). As shown in Fig. 16, the fork mounted to an arm which traveled along the line to remove the meat from the shell.
3. Conclusion

As can be seen from all of these patents, continued structural innovation and technological progress had been made during the past 60 years. As a summary, important advances are as follows:

(1) Less labor. The development of the machine significantly reduces the intensity, difficulty, and occupation of labor.

(2) Better quality. Firstly, less labor occupation leads to less contamination. Secondly, with the improvement of the deveining station, the deveining gets cleaner. Thirdly, the meat breakage is lower because of the better cutting and separation. All these cause better quality of the end product.

(3) Faster. With the reduction of labor difficulty, the operation rate of the operator gets faster. Thus, it is possible to improve the speed of the conveyor in the premise that the operator still feels comfortable.

(4) Simplified mechanism. Under the premise of the same function, the mechanism is simplified step by step such as the change of the separating station.

(5) More styles of manufactured product. Along with the position of the cutting blade from fixed to adjustable and the disjointing station from nothing to mature, different shrimp products can be processed in one machine and the change from one style to another requires very simple operation. All these improvements make the product styles meet customers’ need better.

In a word, the machine featured with a rotary plate is a kind of efficient shrimp peeling mechanism. Nevertheless there is some room for improvement. First, better quality of shrimp product, higher processing rate, and more simplified mechanism are required. Second, the present machine can only process the shrimp beheaded, and it is needed to have an operator to arrange the shrimp into the tray. So there is still work need to be done on how to feed continuously and automatically. Third, more components could be adjustable to get uniform performance regardless of the different size of shrimp and be changeable to make the maintenance of the machine easy.

Acknowledgements

This work was supported financially by the China National Science and Technology Support Program (2012BAK08B04).

References

Keith, J. T., Adjustable timing mechanism for shrimp processing machine cutter assembly, American patent disclosure US6533651 (2003).
Keith, J. T., Shrimp processing machine and method of processing shrimp, American patent disclosure US6485363 (2002).