A Potential Domestic Shrimp Deveining Machine Based on Reciprocating Motion of the cutting tool

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Abstract. This article proposes a design of a potentially feasible small-size domestic automatic shrimp deveining machine. In this design, a laser rangefinder is utilized to measure the shrimp's thickness to determine how deep the cutting tool should cut into the shrimp. The specialized cutting tool, which is composed of a blade and a spoon, then cuts the shrimp's back and exposes the shrimp vein so that the spoon can devein it later. By using SolidWorks and SolidWorks Simulation Animation, this design proves to be practical and has commercial potential.

1. Introduction
Shrimp-belonging to the biggest category of crustaceans called Malacostraca-is a type of arthropod living in the water, and it is a valuable seafood resource. The shrimp itself is not only high in protein and cholesterol but also low in saturated fat, rendering it a generally healthy and wholesome food [1]. Thus, shrimp has been a part of the human diet for a long time. Recently, with the improved transportation grid and system brought by the development of technology, people, not only coastal but also inland, are consuming more shrimps. Consequently, shrimp production grows increasingly following the increasing demand. Data from the Food and Agriculture Organization of the United Nations shows that in 2020, the global production of shrimp, prawns, and lobsters has reached 9.3 billion tones [2]. Besides, according to figure 1, the production of shrimps is both ascending and enormous, leading to a rational claim that the commercial potential of the shrimp market is vast.

![Figure 1. Shrimp farming production by region [3].](image-url)
As illustrated above, the shrimp market has great potential. However, with people’s living standards enhancing and their pursuit of healthy food, a potential problem regarding shrimp vein (figure 2) gradually appears. Shrimp vein is not the common-sense blood vessel as people believe but the intestine of shrimps. Even though shrimp is considered tonic, grit, sand and sediments remaining in its vein are highly likely to gather heavy metal and consequently may cause harm to people consuming it [4]. According to a research conducted to investigate shrimps in the surroundings of the Bohai Sea, due to industrial waste discharge into the water, heavy metals, such as cadmium and copper, levels contained in shrimps are much higher than the national seafood safety standards [5]. Apart from health-related issues posed by shrimp vein, taste and flavor are also largely affected by this vein. This full-of-dirt vein makes the appearance of shrimps less appealing, and the existence of this vein contributes not only to the bitterness of taste but also to less satisfaction when people chew shrimps. Therefore, for health and flavor, more and more people choose to devein beforehand.

![Figure 2. A person pulling the vein, a black tube-like line, out of a shrimp [6]](image)

Now the most common commercially available shrimp is like the one as figure 3 shows. These shrimps are processed in factories with heads removed and shells peeled. Nevertheless, the problem of shrimp vein is still not tackled. After purchasing this kind of product, people will have to devein manually. It is indeed that deveining manually is finer and more complete, but it is not ideal because it is laborious, demanding, low-in-efficiency, and can sometimes even lead to injury [7]. While these exist some commercially available tools and machines to help people devein shrimps, some are either hard to manipulate or not ideal for completely deveining shrimps; some are too big to be used domestically; some too expensive for ordinary families to cover. Rather than been used in households, these machines are more suitable in restaurants and factories.

![Figure 3. The most common shrimp product available in grocery [8]](image)
In all, since people’s need for shrimps—healthy and clean shrimps—is rising annually and since the current market lacks proper tools or machines befitting in households, a small-size automatic shrimp deveining machine that can help people devein both raw and cooked shrimps can be largely promising. The following will present some manual and industrial shrimp deveining methods and discuss their vantages and drawbacks. Then a design of a potential domestic shrimp deveining machine based on the reciprocating motion of the cutting tool is proposed, and details of this design will be presented and discussed.

2. Current Shrimp Deveining Methods

2.1. Manual Shrimp Deveining Methods

Figure 4(a) and figure 4(b) demonstrates two conventional and common ways to devein shrimps manually. In figure 4(a), people can pierce a tooth picker through the shell between the second and the third sections of the shell and pull the tooth picker slowly upwards to draw the vein out of the shrimp. This method, however, has some problems. Firstly, this method only works efficiently for raw and fresh shrimp because veins of cooked, relatively staled shrimps are too soft and brittle to be pulled off, thus leading to an incomplete deveining process. Figure 4(b) demonstrates a better way to devein a shrimp completely. People can utilize a knife to cut the back of a shrimp to expose the vein completely, then by pulling the vein out or brushing the shrimp can people generally devein a shrimp completely. This method contains some problems as well. The first is that this method is highly demanding in people’s skill in cutting techniques, so people without sufficient skills may not devein that successfully, even failure may occur. Besides, this method may even render people injured if they do not operate properly.

Based on deveining concepts manually, some tools, as shown in figure 5, are designed and manufactured to help people devein more efficaciously. Insert the manual shrimp deveining tool beneath the back shell and push it towards the shrimp's tail until the shell is detached from the flesh. By using this tool, people can peel and devein shrimps simultaneously. Though this tool seems quite feasible, the extent to which it can handle shrimps of different sizes and whether or not it can process cooked shrimp is still debatable. Besides, people would need some skills to manipulate this tool, and if it is appropriately operated, an injury may occur.
2.2. Extent Shrimp Deveining Machine
Except the above manual deveining methods, there exists special machines to peel and devein shrimps. As can be seen in figure 6(a), this is a Shrimp Peeler machine from the Gregor Jonsson Inc., it can realize the function of dealing with shrimps of disparate sizes and can operate at the speed of up to 5000 shrimps per hour. During the process, a worker places shrimps on the tray on the conveyor. Shrimps will then be sent to operation zone and a rotating blade will cut the back of shrimps to expose shrimps’ veins. Disc with embossments mounted on the rotating blade rotates accordingly and sweeps veins off at the same time. And Figure 6(b) shows the scene when a worker operates this machine. For places where large quantities of shrimps are needed to be processed within a short time, such as food processing factories and seafood restaurants, this machine works quite well, but for families, this machine appears to be unnecessary. Based on manual shrimp deveining methods and current shrimp deveining machines’ working principles, a potential small-size automatic shrimp deveining device is devised and will be discussed in the followings.

Figure 5. Manual shrimp deveining tool [11]

(a). A worker placing shrimps onto the Shrimp Peeler
(b). The size of the Shrimp Peeler in comparison to a man

Figure 6. Commercial Shrimp Peeler designed by Gregor Jonsson Inc [12].

3. Design Method
Figure 7 is a flow chart illustrating the process of how this design is put forward. At first, an idea to design a machine to help people devein shrimps is generated, then background information investigation, including shrimp market investigation and literature review, is done to propose feasible approaches. Because this machine is targeted at domestic usage, properties such as operability, convenience, cost performance, and the completeness of deveining are taken into account to assess
these approaches. After obtaining a feasible approach that meets the criteria, the CAE software SolidWorks is utilized to model this design based on actual parameters. SolidWorks Simulation Animation is used to verify this design's feasibility, and the result turns out to be promising.

4. Current Shrimp Deveining Methods

4.1. Detailed Description of the Design

Figure 8 demonstrates the front view of the shrimp deveining device 3D model built in SolidWorks. The dimensions of this design are approximately 300mm in length, 80mm in width and 170mm in height. Generally, this device is small in size, leading to easiness to be put on dining table so as to be manipulated readily during or before dinning. This device can be divided into four systems: fastening, motion, control, and deveining systems.
The fastening system, as shown in figure 9, consists of a base where unprocessed shrimp is placed on, four clamps coated with anti-slippery rubber and four clamp-bases in which springs are acting as fastening force. This fastening system can hold tight a shrimp to the maximum width of 24mm, rendering it adaptive to most edible shrimps in the market. And clamps with food-grade anti-slippery rubber can fasten shrimps readily, preventing it to slide away or other unwanted results and thus make subsequent operation going without potential hitches. The reasons behind using springs rather than pneumatic cylinder or other mechanism are that the spring itself is enough to provide force required to fasten the shrimp, also, the simple mechanical device spring can decrease the overall cost of this machine, thus enhancing its cost performance. In addition, with springs as fastening force can make this device more reliable due to its relative simpleness in structure.

![Figure 9. Fastening system](image)

The motion system consists of the horizontal linear actuator and the vertical linear actuator that control the motion of deveining system. In the horizontal direction, on account of the need for support for the blade, spoon, laser rangefinder and vertical linear actuator which are all integrated into a monolithic, using a sliding rail can address this issue properly and with the help of the linear actuator, that monolithic can move horizontally smoothly. In the vertical direction, since the blade should be controlled to prevent it from cutting off the shrimp, so the linear actuator can also address this issue to precisely control the motion of the cutting tool. In addition, due to linear actuator’s small vibration during work, small in size etc., it is favourable to be used in food processing.

The control system, which is also the controller of this machine, is responsible for the control of the motion system, data analysis and man-machine interaction. The novel aspect of this shrimp deveining device is that it provides two shrimp processing methods: automatic or half-automatic. In terms of automatic, just as this word implies, the controller itself, based on database imbedded in the controller, will determine how to process the shrimp placed on the shrimp base. In terms of half-automatic, operators can interact with the controller and customize the cutting depth, moving distance and so on to meet their special needs. With these two ways of controlling, the flexibility of this machine is greatly enhanced.

The core and the most experimental part of this machine is the design of the deveining system. In comparison to most commercially available shrimp deveining machines that use blade with embossment on both sides of the blade to cut the back of shrimps and scrub the shrimp vein off, this shrimp deveining machine works based on reciprocating motion of the cutting tool-composed of a blade and a spoon(see in figure 10)-to cut the back of the shrimp and devein. Apart from that, a laser rangefinder is utilized to measure the thickness of shrimps to determine the depth that the blade ought to cut.
During actual operation, after the operator fastens a shrimp on the fastening system, if the operator chooses the automatic way, under the control of the controller, the horizontal linear actuator functions, driving the laser rangefinder to scan the shrimp and acquire the data. Since the shrimp vein is just beneath the shell, cutting a third of the shrimp's thickness is enough to get the vein exposed, and the completeness and appearance of the shrimp will not be affected too much. When the controller fully analyses data, the exact depths of how much each section of the shrimp should be cut into are obtained. Driven by the horizontal and vertical linear actuators and according to the data obtained, the cutting tool, which is the blade, cuts into the shrimp and moves continuously towards the tail. Furthermore, since the spoon's width is larger than that of the blade, the spoon itself can expand the incision to expose the shrimp vein better. When the blade finishes the cutting process and reaches the shrimp's tail, the cutting tool moves reversely, allowing the spoon to "dig out" the vein. Due to the fillet of the edge of the spoon, shrimp flesh will not be damaged.

In all, the advantages of this design are not merely small in size and efficient in deveining, but also it can deal with shrimp of different sizes. Meanwhile, since this design does not incorporate the idea of dragging or scrubbing shrimps' veins, it can process both raw and cooked shrimps. Materials of the blade and spoon can be stainless steel to increase its durability. Moreover, both the blade and spoon are replaceable and detachable, rendering it easy for people to clean and maintain it.

4.2. Operation Procedures

Figure 11 illustrates how this deveining machine works in the form of flow chart. When the machine is turned on, the operator places the unprocessed shrimp onto the shrimp base and fastens it. Then based on their needs, the operator can whether choose automatic or half-automatic. If he or she choose the automatic process, then the controller will first control the horizontal linear actuator to drive the laser rangefinder to scan the shrimp and obtain the thickness data and analyse the data. After the data is analysed and exact cutting depths are acquired, the cutting tool will cut into the shrimp and expose the vein and then moves reversely so that the spoon can devein the shrimp. If he or she choose the half-automatic process, then the operator will have to input the cutting depth, length, and other parameters to make the machine work as he or she customises. After the cutting tool returns to the original position, the operator can take out the processed shrimp, clean the spoon and continue to process another shrimp.
5. Conclusion
In conclusion, this article proposes a design for a potential domestic shrimp deveining machine based on reciprocating motion of the cutting tool. A model is built in SolidWorks and Simulation Animation is made to verify the feasibility of this design. Consequently, the result turns out to be quite promising: this machine can not only efficaciously devein shrimps, but also proves to be competent in market. Also, this design provides some reference and foundation for future development of this research field.

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