An ergonomic approach to oyster knife design and evaluation – a preliminary result

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Abstract: Oyster as a popular and much beloved food, rich in nutrition and unique in flavor, has been cultivated widely in the world. Taiwan has a history of oyster farming over 300 years. The recent farming areas spread mainly along the southwestern coast of Taiwan, generating about 90% in its total output. Oysters in Taiwan are mainly sold in seafood market with only the flesh. Therefore, oyster is shucked right away once it has been collected from the culturing farm. This paper presents a study on the local oyster shucking tools, consisting of two phases. First, a field survey was conducted to investigate the shucking method, shucking knives used, and possible injuries and disorders experienced by shucking workers. The field survey reveals that, in practice, there are two methods in the shucking process, each using specific shucking knives with different shapes and dimensions, usually made by local blacksmith shops. In total, 5 different shucking knives were collected. Furthermore, the interviewed workers also reported different injuries and disorders experienced from their work, mainly concentrated on the forearm such as cutting on the palm and fingers, pain on the wrist and forearm. In the second phase, ergonomic hand-tool design principles are used to propose improvements in three redesigns of oyster shucking knife.

Key words: Oyster, shucking knife, forearm injury

1. Introduction

Although many production processes have been replaced by machine, hand tools are still primary tools. Well-designed hand tools may play an important role in decreasing occupational injuries. Tichauer reports a comparison of different designs of pliers on electronics assembly trainees and found that poor design of hand tools may result in trauma accumulation and disorders [1]. Connection of hand tools and injuries also has been proved by Aghazadeh et al [2]. Ergonomically well-designed hand tools not only reduce the risk on working period but also provide an efficient, comfortable way to the use of hand tools. Motamedzade et al. examined and redesigned carpet weaving hand tools from ergonomic aspect, hence reduced the injury associated with hand tool use [3]. Oyster as a popular and much beloved food, rich in nutrition and unique in flavor, has been cultivated widely in the world. Due to variations of cultivating conditions, growing environments, and dietary culture, there are differences between countries in the method of eating and cultivating. The history of oyster farming in Taiwan has been over 300 years [4]. Oysters in Taiwan are mainly sold in seafood market with only the oyster flesh. Therefore, oyster is shucked right away once it has been collected from the culturing farm. Due to great variation of shape and size of oyster shells, the shucking process is generally operated manually. Knives used by shucking workers to open oyster shells and remove the flesh are usually made by local blacksmiths, with different shapes and dimensions. Comfort and safety of shucking knife still need to be examined from ergonomic point of view. This study consists of two main phases. The first phase is to conduct a field survey to investigate how oysters are shucked, the tools used in the shucking process, and possible injuries and disorders experienced by the shucking workers. In the second phase, ergonomic hand-tool design principles would be used to propose improvements in three redesigns of oyster shucking knife.

2. Field survey

According to the Fisheries Agency of Taiwan's Council of Agriculture, the framing areas of oyster culturing spread mainly along the southwestern coast of Taiwan in four counties, including Changhua, Yunlin, Chiayi, and Tainan (Figure 1), with about 90% of the total output of Taiwan [5]. Therefore, the researchers spent four weeks (April 11 – May 3, 2009) touring these four counties to visit the local shucking workers. Totally 23 shucking sites were visited and 28 shucking workers observed and interviewed. In observation, photography and videotaping techniques were applied to record the oyster shucking process as well as the tools used. Then a questionnaire was used to collect the shucking workers' personal details and possible injuries and disorders they have experienced.

2.1 Shucking worker profile

Table 1 indicates personal details of the shucking workers. Totally, 28 shucking workers (27 females and 1 male) participated in the interview and all are right handed. From Table 1, we discover that the members of this working group are relatively of older age (mean = 51.8 yr.). The shucking workers are almost all females with only one exception – a 58 year old man working together with his 59 year old wife. One possible reason for this may be that in the oyster cultivating and manufacturing process, physical strength of oyster shucking is less demanding than other activities. Since the oyster farming industry is mainly a family-based operation, therefore, in the cultivating process, with the youths in the family going away to work in the service and/or industrial sectors, elder males in the family would work for tasks of farming and harvesting and elder women for oyster shucking as a division of labor. The young members in the family would join this work during their vacations or job hunting periods on a part-time basis. This is a common phenomenon in agricultural areas as well as in aquacultural sectors in Taiwan. For example, in the field survey, we met two female students part-timely helping their parents in oyster shucking. They are 17 and 19 year old with working experiences 2 and 0.5 years respectively. Due to their specialty in status, we didn't count their data in this survey.

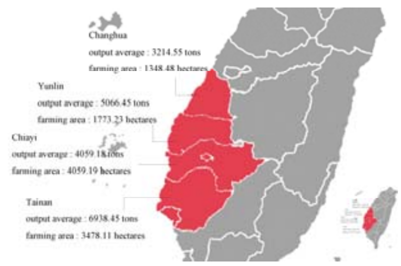

Figure 1. Distribution of oyster farming area in Taiwan

Table 1. Some personal details of shucking worker (N = 28)

Details	Average (SD)	Min-Max
Age (years)	51.8 (13.4)	20.0 – 73.0
Weight (kg)	60.9 (11.0)	40.0 – 83.5
Height (cm)	158.3 (5.0)	150 .0- 170.0
Width of palm (mm)	73.3 (6.2)	59.0 – 88.0
Index finger palm diameter (mm)	36.0 (3.1)	29.1 - 42.4
Middle finger palm diameter (mm)	40.6 (0.6)	34.4 - 49.2
Length of index finger (mm)	75.1 (5.5)	65.0- 90.0
Shucking experience (years)	28.5 (17.0)	0.5 – 58.0
Daily working hours (hr)	8.8 (2.4)	4 .0- 12.0

2.2 Shucking methods

As to the method of oyster shucking, from field survey two existing shucking methods were observed, their respective processes can be described briefly as follows: I) Changhua and Yunlin (Figure 2): The oyster is put against a table surface with the non-dominant hand, and the dominant hand would hold the shucking knife and insert its tip into the hinge of the shells. The knife is then twisted to pry open a seam between the shells while the index finger of the dominant hand clipping on the top shell, which is then removed and put into a basket under the table. Finally, the dominant hand would scrape the knife along the inside of the bottom shell under the meat to separate the meat from the shell, which is now held in the palm of the other hand.

Figure 2. Snaps of shucking method I, Changhua and Yunlin

Figure 3. Snaps of shucking method II, Chiayi and Tainan

II) Chiayi and Tainan (Figure 3): The oyster is held in the non-dominant hand and the dominant hand would hold the shucking knife and insert its tip into the gill side edges of the shells at a spot close to the adductor muscle. The rest of the activities are exactly same as those in method I (these pictures are captured from video that taped during the field survey).

2.3 Shucking knives

Table 2 lists details of the shucking knives collected. Knives A and B were from Changhua and Yunlin used in shucking method I, and knives F, G, H were from Chiayi and Tainan used in shucking method II. Dimensions of shucking knife from Changhua and Yunlin are longer than those from Chiayi and Tainan. In the knife handle, all knives are made of wood with a cylinder shape taping toward the blade end. An exception is knife G, which has a handle of rectangular prism. The average handle length of A and B is 85.8mm, and that of F, G, and H is 48.3 mm. According to ergonomic principles, the length of tool handles should be larger than the palm width in order to avoid excessive tissue compression [1]. Therefore, knives A and B may generate less pressure on the palm than F, G, and H while in use. As to the knife blades, all knife blades were forged from iron stick of different cross section shapes. The cross section of the iron stick used for knives A, B, G, H are rectangle, while that for F is circle. The sticks either have a spear head with pointed tip with sharp edges or simply have a pointed tip at the end.

Table 2. Details of shucking knives

Knives	Total length (mm)	Handle length (mm)	Max handle diameter (mm)	Blade length (mm)	Blade width (mm)	Shucking Method
A 	183.8	85.8	24.3Ø	88.0	10.0	I
B 	206.0	85.8	24.3 Ø	110.2	10.0	I
F 	140.2	51.0	23.0 Ø	81.2	10.0	II
G 	150.8	50.8	23 x 20	100.0	5.0	II
H 	127.0	43.0	25.4 Ø	74.0	8.0	II

Table 3. Differences in shucking methods used in different locations

Location	Changhua and Yunlin	Chiayi and Tainan
Oyster holding	I) Put oyster against table surface	II) Hold oyster in hand
Inserting point	Hinge of shells	Gill side edges
Knife used	A  B 	F  G  H 

Table 3 summarizes the differences in shucking methods used in different locations. There are 3 significant differences: oyster holding method, inserting point, and knives used. Method I puts oyster against a table surface while shucking it and method II holds the oyster in hand. As to the inserting point, method I inserts from the hinge side and method II inserts from the gill side. Comparing knives that used in method I and method II, the mean total length of A and B is longer than that of F, G, and H. This phenomenon indicates that method I prefers a longer total knife length and method II prefers a shorter one.

2.4 Injuries and disorders

In oyster shucking, the workers not only have to exert force while inserting the knife and prying open the shell, their forearm has also to move frequently. This might be a major liability resulting in injuries and disorders in the forearm. Among the 28 shucking works we obtained the following results: disorders concentrating on wrist (83.3%), palm (53.3%) and fingers (76.7%), as shown in Table 4. The high percentage of injuries and disorders may depict a necessity for tool redesign and/or work method revision. After further discussions with the workers, we analyzed the possible causes of these injuries and disorders. The wrist disorders are mainly resulted by repeated movement; the palm injuries include knife cutting and tissue compression. The finger injuries mainly concentrate on the index finger during the working period. In shucking, a featured posture is that the shucking worker would rest the index finger on the blade stick to assist guiding it during the inserting and the scraping process (Figure 4). Hence, the frequent movement and the pressure on the index finger contribute mainly to the resulted disorders. In addition, non-ergonomic oyster knife also results in some disorders such as: tissue compression in the palm with a short handle, wrist deviation and flexion in knife using. The exterior of the oyster shells is not only hard but also sharp with irregular protuberances. Therefore, shucking workers have to wear gloves to protect their palms and fingers, especially the non-dominant hand which has direct contact to the oyster while holding it.

3. Shucking knife redesign

3.1 Redesign

In this phase, ergonomic hand-tool design principles are used to propose improvements in the oyster shucking knife redesign. The handle is a critical component in shucking knife design. Since the shape of the tool handle

Table 4. Disorders of shucking workers in six months prior to the survey (N = 28)

Regions	No.	%
Neck	7	23.3
Shoulder	8	26.7
Wrist	25	83.3
Palm	16	53.3
Finger	23	76.7
Waist	16	53.3

Figure 4. The index finger usually rests on the blade stick to assist the blade in prying and scraping.

will affect the holding posture of the tool, the shape of the handle is a primary factor in reducing or eliminating user fatigue [6]. Physical factors taken into consideration in developing new handle models are described below:

1) The major muscles which flex the fingers and generate grip force are located in the forearm. These muscles have long tendons which span the wrist joint. Thus, the gripping capability of the fingers is affected by the position of the wrist [6]. According to Tichauer's suggestion, continued use of hand tools with the wrist in a bent position can cause inflammation, chronic pain, and possible permanent injury both to the synovial sheaths protecting the tendons of the wrist and to the median nerve passing through the wrist [1].
2) For greater comfort of use and least stress, the tool handle should be oriented so that, while working, the hand and the forearm should be aligned to avoid ulnar or radial deviation. Deviations of the wrist from the neutral position under repetitive load can lead to a variety of cumulative trauma disorders as well as decreased performance [6].
3) If a tool has a short handle that does not span the breadth of the palm, high forces can be created at the center of the palm. Thus, the tool handle should be designed to extend beyond the hand when gripped [6].
4) Freivalds summarizes the results from some experiments of handle diameter, the handle diameters should be in the range of 31-51mm with the upper end best for maximum torque and the lower end for dexterity and speed [7].
5) The cross-sectional configuration of the tool handle directly affects the operator's performance and health. The forces generated during use should be distributed on as large a pressure area of the palm as possible [6].

Based on the above listed principles, it is obvious that some of the existing oyster knives may not be ergonomically designed in shape and/or in dimensions. Accordingly, three redesigned oyster knives, coded with X, Y, Z (Table 5) are proposed for further validation. These redesigned knives are supposed to be suitable for either of the two shucking methods. The physical characteristics of the redesigned knives can be briefly described as follows:

X: The handle is bent with a protrusion on the top. This design provides a large contact surface to distribute the force over a larger area, i.e. the protrusion on the top would spread the pressure over the tough tissues between the thumb and index finger. Sharp corners and edges in the original designs are replaced by curves and smooth surfaces in this design. Angle of the knife handle and the blade is bent in 20 degrees to maintain a straight wrist while the tool is in use.

Y: The handle is oval shaped and with a neck. Sharp corners and edges are replaced by curves and smooth surfaces. Circular notches on the neck of the handle provide more friction to avoid slipping during shucking.

Z: The handle is extended over the palm length to provide an easier grip and to avoid tissue compression stress. Angle of the knife handle is bent in 10 degrees. This design also provides more friction by slant notches on the handle.

With the handles extended, the blade of the redesigned knives is then shorter than those of the originals. In addition, the blade in all these 3 redesigned knives has sharp edges and a pointed tip which simulates a drill-tip for providing an advantage in prying open the shells in the shucking process. A wider blade is considered to provide more torque leverage to open a seam.

Table 5. Details of the redesign shucking knives

Knives		Total length (mm)	Handle length (mm)	Handle diameter (mm)	Blade length (mm)	Blade width (mm)
X		166.0	103.0	Oval-section (long axis = 42.0mm, short axis = 32.0mm)	63.0	15.4
Y		165.4	102.4	Oval-section (long axis = 42.5mm, short axis = 36.0mm)	63.0	15.4
Z		171.6	108.6	Oval-section (long axis = 45.0mm, short axis = 31.0mm)	63.0	15.4

3.2 Discussion

As mentioned previously, handle affects not only the postures of shucking workers' hands but also the level of comfort and operational performance. Therefore, ergonomic principles were applied to redesign the handle for improvement, such as providing a larger contact surface to reduce pressure on the palm; the angle of the knife handle and the blade is bent (X: 20 degrees; Z: 10 degrees) to maintain a straight wrist while the tool is in use, and extended handle length over the palm to provide an easier grip and to avoid tissue compression stress. Preliminary field tests of the redesigned knives were conducted by shucking workers in Yunlin (with method I) and Chiayi (with method II). Suggestions made by the participant shucking workers for the redesigned knives are presented below.

About the knife handle

Comparison of the handle lengths of original knives and the mean palm width of the workers reveals that the handle length of knives A and B (A = B = 85.8mm) is longer than the mean palm width (73.4mm). However, the handle lengths of knives F, G, and H (F = 51.0, G = 50.8, H = 43.0mm) are shorter. Therefore, A and B would produce less tissue compression in the palm during the shucking period. In the preliminary field test by shucking workers, we found that shucking workers adopting shucking method I (holding the oyster against a table surface) prefer knife X. However, the redesigns were not preferred by shucking worker adopting method II (holding the oyster in the hand). A possible reason might be that in shucking method II a shorter knife handle length is more flexible to use.

Sucking workers commented that these knives would be held with a fixed hand-posture because of the physical features designed into the oyster knives. For example, knife X has a protrusion on the top of the handle surface which defines the holding position and also restricts the knife user from freely adjusting his/her holding postures as compared to the original shucking knives.

About the knife blade

The blade of the redesigned knives is shorter than those of the originals (X = Y = Z = 63.0mm vs. A = 88.0mm, B = 110.2mm, F = 81.2mm, G = 100.0mm, H = 74.0mm,). The participants of both shucking methods I and II did not like this shorter blade and felt that their index finger would obstruct the shucking operation using the redesigned knives.

5. Conclusion

This study first surveyed the existing oyster shucking methods and knives used in the field, and the experienced injuries and disorders among the shucking workers in Taiwan. Then based on ergonomic hand-tool design principles, three redesigned shucking knives were proposed for further evaluation and validation. Result of this study can be summarized as follows. 1) There are two existing shucking methods used in different geographical locations. 2) Different shucking knives are used in different shucking methods. Comparison of the different knives in different methods reveals that the knife lengths vary greatly. 3) The shucking workers reported different injuries and disorders experienced from their work, mainly concentrated on wrist (83.3%), palm (53.3%) and fingers (76.7%). The high percentage of injuries and disorders may depict a necessity for tool redesign and/or work method revision.

The five shucking knives collected during the field survey were examined from the point of view of ergonomic design and three redesigns were then proposed and field tested with shucking workers and opinions and suggestions gathered. In the next stage, a new version of the redesign will be developed based on the opinions and suggestions made by shucking workers in the preliminary field test. Features could be considered in the new version would include: handle material and blade length. The handle material was not seriously considered in the proposed redesigns. However it can affect firmness and comfort of handle grip. In addition, the redesigned blades were shorter than the originals (blade length of redesigns = 63.0mm) and were disliked by the shucking workers. Since the shucking workers have a mean index finger length of 75.1mm, therefore we conjecture that this might cause their index finger to obstruct the shucking process if they as usually rest the index finger at the blade side while shucking. Thus, this anthropometric dimension of shucking workers should be taken into consideration in designing the blade length.

The effect of the new shucking knives on shucking workers' performance was not investigated in this study. Further field trials should be conducted to test operation efficiency under real production conditions. To evaluate the operational performance between original and redesigned knives, we may adopt the evaluation form developed by Dababneh [8] to test operators in the field. An example could be referred to Motamedzade [3] in revising this form to his field test for carpet weaving workers. In addition, laboratory experiments can also be conducted to evaluate the redesigned shucking knives by measuring their pushing and twisting forces. These two forces are used in shucking period mostly. EMG measure could also be applied to compare muscle exertions between original shucking knives and the redesigns.

Examination of hand tool design from ergonomic point of view reduces the injuries and disorders due to hand tool using. However, the shucking workers seem to concern more about working performance in the shucking period. Furthermore, injuries and disorders distribute not only on the forearm, but also on the neck, shoulder and waist. Thus, relationship between working station arrangement, working posture and physical injuries and disorders should also be observed in greater detail and evaluated in ergonomic aspect in the future.

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