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Study on Influencing Factors of mussel shell unilateral shelling test based on water jet technology

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Abstract

Based on the study of the water jet technology of the single side shell of the thick shell mussel, in the experiment of water jet shelling, in order to grasp the three influencing factors of shelling quality of mussels with single side by water jet to the greatest extent: the injection pressure of water jet, the distance between spraying targets and the incidence angle of water jet, the data of mussels with thick shells and the numerical range of experiment were carried out. By measuring and theoretical analysis, the best three experimental parameters of water jet mussel unilateral shelling are obtained.

Key words: mussel shell,water jet,fitting curve,jet incidence angle,experimental parameters

1. Introduction

Mussel，or called Mytilus ,Its meat is delicious, rich in nutrients, rich in protein, known as the "sea egg"(Zhu Beiwei, &Xue Chang Hu,2016). Mussel meat contains 53.5% protein, 6.9% fat, 12.7% carbohydrates, and abundant inorganic salts such as calcium, phosphorus and iron. The Mytilus mussels also contain vitamin B and a variety of trace elements, which have anti fatigue, lowering blood pressure, reducing blood lipid, anti-tumor function and anti-inflammatory activity, such as health function(Li Naisheng&Xue Chang Hu,2010; Xin Hua Zhong, Chen Lu, Wu Jun, et al,2013). Shellfish culture plays an important role in China's fishery economy, and its output has always accounted for a large proportion of cultured shellfish in China(Liu Hongying,2006; Guo Yuhua, Li Yujin ,&Wu Xinying,2011;Li Pingping,2006).At present, mussels exist mainly in the form of peeling off half shells in import and export trade, which is convenient for consumers to eat. However, there is almost no processing technology for mussels to peel off half shells so that the meat quality remains on half. The research methods of this kind are at the initial stage.

At present, the shelling method of mussels at home and abroad, according to the classificationof food physical processing methods(Torsh ,&ParkerR,1907; Jia Jing dun,2016), can be divided into two kinds of shellfish dehulling methods: non thermal physical dishulling and thermophysical dehulling, the former mainly includes mechanical shelling(Mackin, Nelson, &Tretsven,1971), ultra high pressure shelling method.(EA Voisin,2000), water jet dehulling method (Sugiyama,2004), and the latter mainly includes heating dehulling method(Doxsee,&Cook,1935), microwave shelling method(Lu Xin Chun, Xing Zhao, &Wang Wei,2015), infrared shelling method(Wlleaton,1971). All these methods are all shelling of mussels, and there are few methods and techniques for single side shelling of mussels. The traditional way is still manual operation for single side shell. By analyzing the physiological structure of mussels(Figure 1), it is possible to know that the connection force of the mussel’s meat and shell are concentrated on the adductor (Duan Wei Wen, Luo Wei, et al,2013). Therefore, the removal of the shell from the inner surface of the shell can be used to remove the shell. The water jet stripping of bay scallop shellfish with water jet was studied by Xie qiuyang and relevant researchers (Xie qiuyang, Wang Jiazhong, &Yi Jing Gang et al,2014)， they used the simulation of water jet nozzles and experimental design of water jet peeling shellcolumn, fresh and pollution-free shellfish were obtained. Referring to the method of water jet, a new type of shelling technology for mussel is presented in this paper. Through the curve fitting of the curve of the shell curve of the shell length and the shell height in two directions and the data of the reverse curve point, the range of the incident angle of the two directions is finally obtained and the rationality of it is tested by the test. The jet ejection distance and the jet pressure are proved to be the factors affecting the effect of the shellfish shelling. And the reference range of jet pressure and jet distance was obtained through water jet mussel unilateral shelling test.

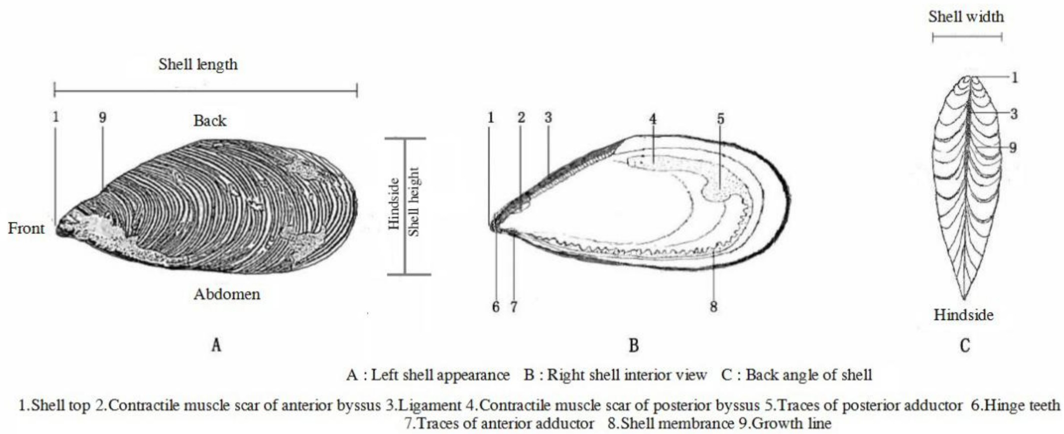

Fig.1. Physiological structure of mussels

2. Analysis of the influence factors of the test

2.1 Analysis of incident angle of water jet

2.1.1 The establishment of the structure coordinate system of mussel

The key to single side shell removal by water jet technology is to destroy the connection of the closed shell muscle, which requires the jet of water jet to the position of the closure of the shell muscle, which destroys the water jet to be ejected along the surface of the shell. The shell is ejected along the shell surface in the direction of shell length and shell height, and the jet direction is at the back of the shell and the direction of the shell, so the minimum incident angle of the jet in two directions is determined.

Fig.2. The structure coordinate system of the left half shell of mussels

For this reason, 30 mussels with shell length (L) 100mm-110mm and shell width (H) 50mm-55mm were selected to measure the position of the left shell muscle of the shell and take the direction of the shell (L) as the Y axis, and the direction of the shell height (H) as the X axis, and the Cartesian coordinate system was set up as shown in Figure 2. The Yellow irregular circular face is the closed muscle area, the point P_1 is the center point, and the concave point P_2 of the inner shell is shown in the figure. After measuring the shell length and shell width of 30 mussels, the average value of the measured data was obtained. The average value of the shell length and the shell width of the left half shell of the mussel was 105mm and 48mm respectively. The mean value of the P1 abscissa of the central point of the occult muscle was 21.71mm. P_1 is the perpendicular line of the Y axis. The intersection point of the vertical line and the edge of the mussel is recorded as M, the distance between the point M and the Y axis, that is, the distance from the most edge of the mussel shell, and the average value is generally 5mm.

2.1.2 Curve fitting of the shell section of mussel

The special structure of the two half shells of the thick shell mussel determines that the jet incident angle of the jet in the direction of the shell length and the height of the shell is determined when the water jet is used for the single side shell removal of the mussel, including the ejection closure and the spray mantle. To this end, we need to plot two directions of the shell curve.

(1) The curve of the high direction section of the shell

The experiment showed that the shell meat of mussel mostly depended on the right shell while the left shell was mainly the outer membrane and the adductor muscle. The left half shells of the 30 mussels were plotted along the shell height direction by snake ruler, and the curves of P_1 section in the center of the adductor muscle and P_2 section through the concave point of the inner shell were obtained. The curves S_1 and S_2 were shown in Figure 3.

Fig.3. Measuring method of shell section curve

We can use the software of Getdate Graph Digitizer to measure the coordinates of the points on the two shell section curves and reverse them, and use the SPSS data to get the data obtained from the 30 sets of inverse curves.In order to get the average shell section curvature, the 30 groups of data were obtained by fitting the horizontal and vertical coordinates respectively.The fitting curve S1 of abscissa X and shell width coordinate Z is obtained, as shown in Fig.4, where the Z axis is perpendicular to the plane of the X-Y axis and the common origin. The regression equation of the fitting curve S_1 is as follows:

$$z_1 = -4.507\times10^{-7}x_1^{5} + 3.496\times10^{-5}x_1^{4} - 9.414\times10^{-4}x_1^{3} - 3.561\times10^{-3}\times x_1^{2} + 6.628\times10^{-1}\times x_1 + 0.160 \quad (1)$$

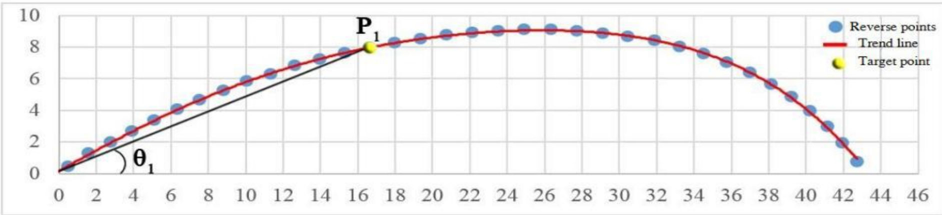

Fig.4. Fitting curveS1

As the starting point (M point) of the fitting curve S1 of Surveying and mapping does not coincide with the origin of the X axis, in order to facilitate the analysis and fitting of the point coordinates on the curve in the plane of the coordinate axis, the fitted curve of the mapping is moved to the X axis and the M points on the fitting curve S1 coincide with the original point. Then the abscissa of point P1 is taken as 21.71-5=16.71.We can bring the abscissa 16.71 of point P1 into formula (2) to get its corresponding Z axis coordinate value，and the coordinates of P1 in the fitting curve S1 are (16.71, 7.99).The angle between the point and the X axis of the coordinate origin isθ1, which is the minimum incidence angle of the water jet.. The linear equation is as follows:

$$z = 0.478x \quad (2)$$

The minimum angle of incidence is derived from the formula (2)： θ1=arctan(0.478)= 25.548°≈25°.

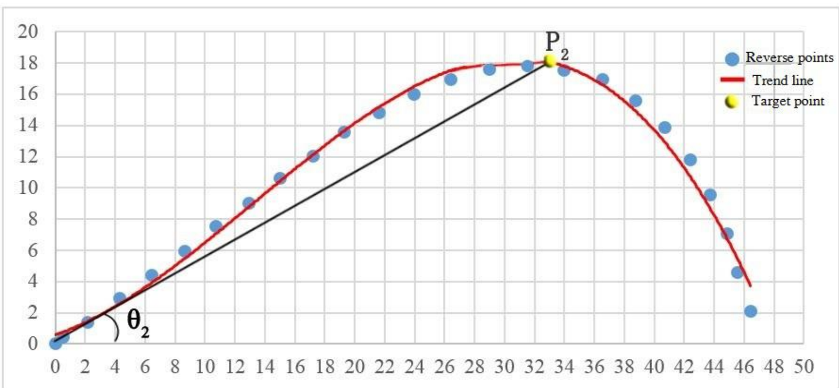

Fig.5.Fitting curveS2

Similarly, the fitting curve S2 is shown in Figure 5. The S2 regression equation of the fitting curve is as follows:

$$z_2 = -8.714 \times 10^{-4} x_2{}^3 + 3.481 \times 10^{-2} x_2{}^2 + 3.301 \times 10^{-1} x_2 + 0.589 \quad (3)$$

The point P_2 is located at the most concave part of the shell of mussel, that is, the highest point of the shell. Because the S_2 curve is parabolic, the ordinate value of the point on the fitting curve S_2 is about half of the width coordinate value of the mussel shell at this point(Zhang Yihao,2009; Martin, &Hall,2010). After measuring 30 mussel samples, the average value of the ordinate is 18mm， and the substitution type (3) obtains three x_2 values and 33.316 according to the actual situation. Then the P_2 coordinates are (33.316,18).The corresponding angle between the point and the origin of the coordinate and the X axis isθ_2, which is the minimum incidence angle of the water jet. The linear equation is as follows:

$$z = 0.54x \quad (4)$$

The minimum angle of incidence is derived from the formula (4):

$$\theta_2 = \arctan(0.54) = 2828.369° \approx 28°$$

(2)The curve of the long direction section of the shell

Several experiments have proved that the link between the mantle and shell of mussels can be destroyed when water jet is jet to the high direction of the mussel shell, but the closure of the shell can be adhered to the shell, so it needs to be ejected in the long direction of the mussel shell. 30 other mussels were used to map the cross section curves of the P_1 shells at the central point of the central point of their occult muscle. The obtained images were obtained by software to get 30 sets of data. The average value was obtained by using the SPSS fitting curve, and the average fitting curve S_3 was obtained, as shown in Figure 6. The regression equation is as follows:

$$z_3 = -2.067 \times 10^{-5} y_3{}^3 - 7.653 \times 10^{-4} y_3{}^2 + 3.186 \times 10^{-1} y_3 + 1.1287 \quad (5)$$

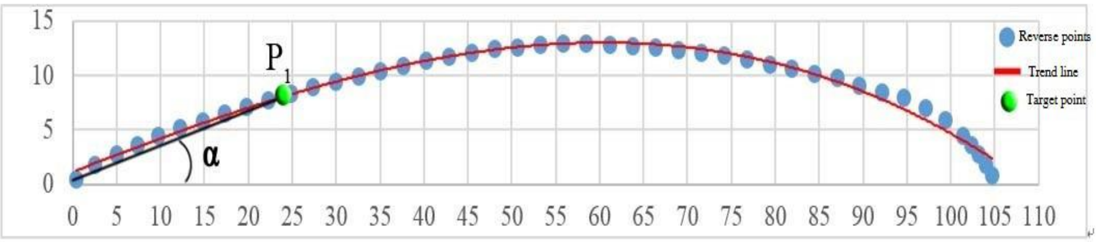

Fig.6. Fitting curveS3

The previous formula (1) has been obtained by the formula (1) to obtain the longitudinal coordinates of the P1 7.99, to replace it (5), and to solve the y_3 value of three. According to the actual situation, y_3 is 24.07, then the coordinates of the P_1 point on the curve S_3 are (24.07,7.99). The angle between the point and the axis of the coordinate and the X axis isα, which is the minimum angle of incidence of the water jet. The linear equation is as follows:

$$z = 0.332y \quad (6)$$

The minimum angle of incidence is derived from the formula (6):

$$\alpha = \arctan(0.332) = 18.366° \approx 18°$$

2.2 Analysis of jet pressure and target distance in water jet

The impact force of the jet on the target decreases with the increase of the target distance, and the impact force is the direct factor affecting the effect of the shell, so the effect of the distance change on the effect of the shell is studied.

According to the relevant research, the relation between the dimensionless target distance s/d and the dimensionless p/p_d is that p/p_d decreases with the increase of s/d. As shown in Figure 7, s is the jet target distance, d is the jet outlet diameter, p is the jet outlet dynamic pressure, and p_d is the stagnant pressure of the jet(Lei Yu Yong,2017; Ni Hongjian, Wang Rui, &Zhang Yanqing,2005). It can be seen from equation (7) that when s, d is constant, that is, s / d is constant, initial velocity V_0 increases with the increase of jet outlet pressure P. Obviously, jet injection pressure has obvious influence on shell peeling effect.

$$p = \frac{1}{2}\rho v_0^{\ 2} \qquad (7)$$

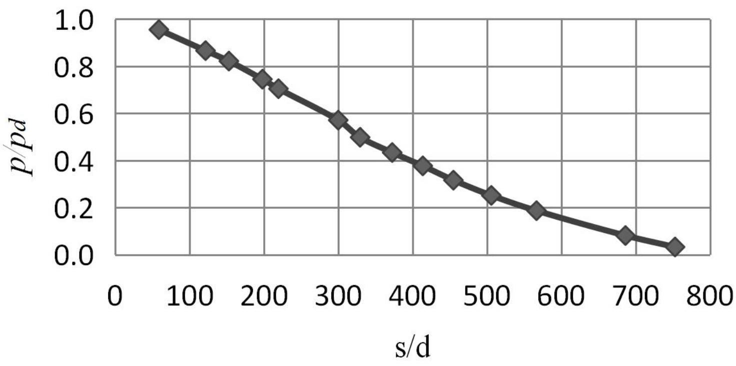

Fig.7.Influence of geometric parameters of typical nozzle runner geometry on nozzle performance

3. Pretest preparation

3.1 Test equipment and materials

The equipment needed in this experiment mainly includes: plunger pump (maximum pump pressure 11MPa, flow 5.7/min), guide plate sector nozzle (outlet diameter 1mm, contraction angle 65°, cylinder length 3mm, as shown in Fig 8), spray gun, hydraulic regulating valve (including pressure gauge range 0~16MPa), clamp device, high pressure hose, pipe support The platform and water storage device, as shown in Figure 9.

The experiment took the thick shell mussel as the test object, and divided into four grades of 80~90mm, 90~100mm, 100~110mm and 110~120mm according to the shell length. In general, the length of the adult thick shell mussel is generally 100~120mm, and extracting30 thick shell mussels which come from 100~110mm grades, and the mussels are cleaned and opened in the shell's abdominal direction as a sample of this test, such as Figure 10.

Fig.8. Guide plate sector Nozzle

Fig.9. Test device components

Fig.10. Test sample

3.2 Test parameter setting

In this experiment, sensory evaluation method was used to analyze and evaluate the tripping effect of the adductor muscle. The key evaluation criteria are: peel off difficulty degree, integrity of shell meat and residual quality of shell surface. The sensory score was based on reference Table 1

Table1　The basis of sensory evaluation for shelling

Grade	Exfoliation difficulty （50points）	Integrity of Mussel's meat （30points）	The degree of meat residue on thesurface of the shell （20points）	Total score （100 points）
Class A	Easy separation of meat from shell （47-50points）	Mussel's meat is complete and has little impact（25-30points）	Few meat residues （15-20points）	>87points
Class B	Able to separation of meat and shell （44-47points）	Mussel's meat is complete, with a small amount of impact trace （20-25points）	A few residues of meat（10-15points）	74-87points
Class C	Failure to separate meat from shell （<44points）	Mussel's meat is incomplete and has a lot of impact marks （<20points）	Fleshy residue is obvious （<10points）	<74points

4. Test content

In this experiment, single factor experiments are carried out on three factors, namely jet pressure, jet incidence angle and target distance. As shown in Figure 11, the components are assembled after determining the performance of each component, and the test samples are fixed on the clamping device and then tested according to the requirements of the test, as shown in Figure 12.

Fig.11. Test device assembly **Fig.12. Mussel fixing device**

5. Test results and analysis

5.1 Influence of incident angle of jet on the effect of shelling

The jet pressure is adjusted to 3MPa and the target distance is fixed to 15mm. In the process of water jetting, the impact of the shell, shell and mantle from the shell length and the high two directions is used, so the incident angle of the jet can't be a single angle. After many experiments, the jet is ejected in the direction of the shell. The minimum incident angle of the jet is 25° -28°. When the water jet is used to spray the shell in the long direction of the shell, the minimum incident angle of the jet is 18°. The incident angle of the water jet is adjusted to the above conditions and is tested. The effect of the shelling is as shown in Figure 13. It was found that under the condition, the mussel shell remained less and the shell meat was intact, indicating that the shelling effect was very satisfactory, and the parameters mentioned above were reasonable.

Fig.13. Shelling effect under the test value of jet distance

5.2 Effect of jet pressure on the effect of shelling

Reference third chapter test peel effect, jet angle of incidenceθ_1 adjusted to 25°, θ_2 to 28°, and alpha to 18°. The target distance is adjusted to 15mm. The order of the jet pressure is adjusted to 1, 2, 3, 4 and 5MPa. The score of sensory evaluation is shown in Table 2, and the corresponding trend curve is shown in Figure 14.

Table2 Sensory evaluation of different jet pressure

Jet pressure（MPa）	1	2	3	4	5
Sensory score	67	78	82	79	69

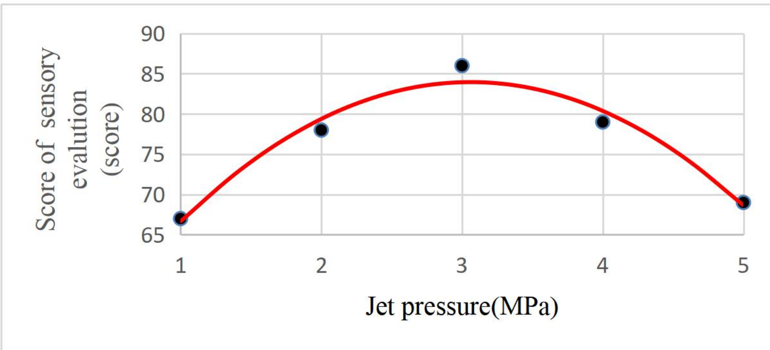

Fig.14. Shelling effect of different jet pressure

Figure 14 shows that when the jet pressure is gradually increased in the range of 2~4MPa, the sensory score of the effect is little changed. When the jet pressure reaches 3MPa, the effect of the shell is best and the sensory score tends to 87. With the continuous increasing of the jet pressure, the effect of the shell is not ideal, and the residue of the shell is more, as shown in Figure 15.

The reason for this is that the attack force on the shell increases with the increase of the jet pressure. When the blow force exceeds the damage strength of the shell, the surface of the shell is uneven and has obvious impact marks, and the inner surface of the shell also has more meat quality. Therefore, the jet pressure is more suitable for 2~4MPa.

Note: from left to right, the shelling effect is 1, 2, 3, 4, and 5MPa respectively.

Fig.15. Shelling effect of different jet pressure

5.3 The effect of target distance on the effect of shelling

The jet pressure is adjusted to 3MPa, and the jet incidence angleθ_1 is adjusted to 25°, θ_2 to 28°, and the α is adjusted to 18°. The target distance of the target is 5 mm, 10mm, 15mm, 20mm and 25mm, respectively. The sensory score values are like table 3, and the corresponding trend lines are shown in Figure 16.

Table3　Sensory score of different target distance

Target distance（mm）	5	10	15	20	25
Sensory score	79	82	87	74	70

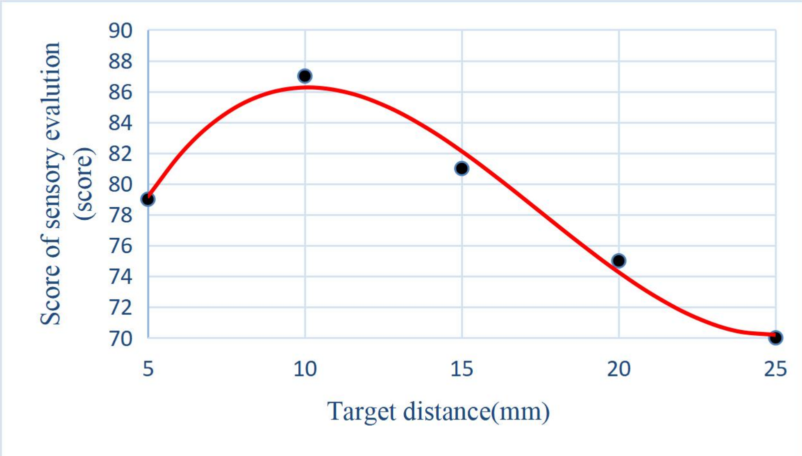

Fig.16. Sensory score of different target distance

From the above graphic data a, it can be seen that when the target distance is below 15mm, with the increasing of the target distance, the sensory score increases gradually and tends to 90 points, which indicates that the effect of shelling is getting better and better. But when the jet distance is too long, the force on the shell is too big, but it can be removed, but it can destroy the integrity of the shell. When the target distance increased to 20mm, the quality of the shell decreased and continued to increase, and there was an obvious jet impact mark on the surface of the shell and the surface of the shellfish. The impact force of the jet on the shell gradually became smaller. The impact force could not overcome the adhesion force between the shell and the shell, and the closed shell muscle could not be completely stripped off. By analyzing and comparing five different injection distances (as shown in Fig. 17), the target distance is suitable for 10~15mm.

Note: from left to right, the target distance is 5, 10, 15, 20 and 25mm.

Fig.17. The effect of different target distance on shelling

6. Conclusion

In order to verify the accuracy and practicability of the parameters of the above parameters, in order to facilitate the practical operation, the jet pressure values are set to 3MPa, and the jet incidence angleθ_1 is adjusted to 25°, θ_2 to 28°, and the α is adjusted to 18°, the target distance is 15mm.And the average of 15 thick shell mussels is divided into 3 groups of A, B and C groups, and verify the results. The results are shown in Table 4 and Figure 18. The test shows that the parameters of the shelling and shelling are reasonable and the shelling effect is ideal.

Table 4 Test results of shelling test

Verification standard	Test grouping			average value
	A	B	C	
Shelling rate %	100	98	100	99.33
Sensory score	89	90	87	88.67

Note: typical shelling effects from left to right are group A, B and C.

Fig.18. Test verifying the effect of shelling

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