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Effect of Salt Concentration and pH value on the Lactic Fermentation Process of Kohlrabi (*Brassica oleracea* L.)

Tran Thien Hien[1,2], Tran Thanh Truc[3,4], Nguyen Van Muoi[5*]

1- MSc. Graduate, Faculty of Food and Environmental Engineering, Nguyen Tat Thanh University, Ho Chi Minh City 700000, Vietnam
2- MSc. Graduate, Institute of Environmental Sciences, Nguyen Tat Thanh University, Ho Chi Minh City 700000, Vietnam
3- Associate Professor, College of Agriculture, Can Tho University, Can Tho City 94000, Vietnam
4- Associate Professor, School of Graduate, Can Tho University, Can Tho City 94000, Vietnam
5- Professor, College of Agriculture, Can Tho University, Can Tho City 94000, Vietnam
*Corresponding author (nvmuoi@ctu.edu.vn)

Abstract
Vegetables have been shown to be able to provide nutrients, including vitamins, minerals and especially fiber, and release toxins that arise during the digestion of food. As a result, the importance of vegetables has been increasingly emphasized in the human diet. In this study, Kohlrabi, a vitamin C-rich vegetable, was used for lactic fermentation. The whole process was optimized by varying a wide range of parameters including concentrations of salt solution and pH value on the growth of lactic acid bacteria, product texture and sensory characteristics. Current results revealed the optimal conditions for the fermentation process are as follows: NaCl solution used of 3.5%, initial pH 4.2, and $MnCl_2$ with a concentration of 30 mM. The obtained Kohlrabi pickle products exhibited acceptable quality and good sensory scores after 2 days. Elevated temperature was also found to be associated with loss of hardness, quality loss and longer fermentation time. Optimized Kohlrabi pickling process will contribute to diversifying pickled vegetable products to avoid the defects caused by improper processing.

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Keyword
Kohlrabi (*Brassica oleracea* L.)
Lactic fermentation
Salt content
Vitamin C

Introduction
Pickling is a widely used and preferred method for processing and preserving vegetables (Aljahani, 2020; Behera, El Sheikha, Hammami, & Kumar, 2020; Ding *et al*., 2018; Rao *et al*., 2020). Pickling vegetables is a lactic fermentation process (Ashaolu & Reale, 2020; Di Cagno, Coda, De Angelis, & Gobbetti, 2013; Panda, Parmanick, & Ray, 2007; Patra, Das, & Shin, 2018; Xiong, Guan, Song, Hao, & Xie, 2012). In the fermentation process, a series of processes occur such as the extraction or osmosis of substances from plants tissues, the process of increasing the biomass of microorganisms (mainly lactic acid bacteria), the process of creating lactic acid, the process of inhibiting the growth of spoilage microorganisms by lactic acid and salt, the process of flavoring the products (Monika *et al*., 2017; Soltan Dallal, Zamaniahari, Davoodabadi, Hosseini, & Rajabi, 2017). The lactic acid bacteria have different activities, so the intensity of lactic fermentation depends on the type of flora present. The form of the

microbiota also influences the characterization of the end products of sugar metabolism. Some lactic acid bacteria convert most of the sugar in the product into lactic acid, while some other lactic acid bacteria produce some by-products in addition to lactic acid, such as acetic acid, ethyl alcohol, CO_2, mannitol, and mannitol dextran (Barbieri, Montanari, Gardini, & Tabanelli, 2019; Chen, Lu, Yu, Chen, & Tian, 2019; De Vuyst & Leroy, 2020; Mora-Villalobos *et al*., 2020). On food vegetables, there are many different microorganisms, including lactic acid bacteria, which plays an important role in vegetable fermentation (Ashaolu & Reale, 2020; Liu, Han, & Zhou, 2011; Nguyen *et al*., 2013). However, not all vegetables can be pickled, because the sugar content of vegetables is different, in order for vegetables to be pickled, vegetables must have a certain minimum sugar content (Scapin *et al*., 2021; Varzakas, Zakynthinos, Proestos, & Radwanska, 2017; Wanselius *et al*., 2019). However, one can add more sugar if the sugar in vegetables is too low. Under the action of lactic acid bacteria (available in ingredients or can be added), sugar will be converted into lactic acid, giving the product a taste (Lošák *et al*., 2011; Rana, Ghabru, & Vaidy, 2019). On the other hand, lactic acid is also a preservative for the produce from spoiling. Therefore, the process of pickling vegetables is a process of both processing and preservation. In this process, the finished product is satisfactory when on the one hand, it produces a biomass of beneficial bacteria that overwhelms the spoilage microorganisms, on the other hand, it imparts a sour taste and a delicious taste to the product, and this process converts vegetables to a "biologically ripe" form with the aim of increasing digestive efficiency.

Recently, nutritional science has concluded that vegetables provide people with many vitamins, minerals and especially fiber, which helps to release toxins that arise during the digestion of food (Chhabra, 2018; Rana *et al*., 2019; Salehi & Aghajanzadeh, 2020; Septembre-Malaterre, Remize, & Poucheret, 2018). Therefore, in the human diet, vegetables are becoming more and more important. In countries around the world in general and in Vietnam in particular, the percentage of vegetables in the diet is increasing thanks to the nutritional content it brings. Currently, Kohlrabi (*Brassica oleracea* L.) is consumed mostly in fresh form (boiled, sautéed), jams, etc. Kohlrabi (*Brassica oleracea* L.) is pickled as a products (Al-Mharib, Al-Saadi, & Almashhadany, 2020; Dhok *et al*., 2020; Lošák *et al*., 2011; Mahdi, Al-Shammari, Alalawy, & Hathal, 2020; Park *et al*., 2017; Salehi, 2019; Ulukapı & Kacar, 2020) which is not new in the application of lactic fermentation, but in fact, pickling Kohlrabi is only based on the old experiences of the forerunners without much research on the process of Kohlrabi products and provide specific suitable conditions for fermentation to give a stable quality product on a large scale.

Therefore, it is necessary to research to find the optimal parameters for Kohlrabi lactic fermentation in order to contribute with further studies to complete the processing of pickled Kohlrabi in households or on an industrial scale, and aims to export to other countries. Completing the Kohlrabi pickling process will contribute to diversifying pickled vegetable products, avoiding defects caused by improper processing.

The purpose of this study is to use raw materials of Kohlrabi grown in Vietnam to conduct unsalted by lactic fermentation. The study carried out the process of investigating the effects of different salt solution concentrations on the fermentation process; monitor the effect of pH of the initial fermentation broth on the growth of lactic acid bacteria during the fermentation process on product quality on the fermentation efficiency to find the optimal parameters.

Materials and methods

Raw materials

The main raw material in this study is Kohlrabi (*Brassica oleracea* L.) which was purchased from Can Tho city (10°1′56.69″ N, 105°47′2.73″ E). Requirements for ingredients such as being fresh, not bruised, uniform in size, lint-free, free from pests and diseases. In addition, all chemicals used in this had analytical grade, and were used without further purification, having been purchased from Sigma Aldrich (Germany).

Processing of Kohlrabi was pickled by lactic fermentation

The process of the Kohlrabi was pickled by lactic fermentation is shown as the diagram in Fig. (1).

The Kohlrabi used for processing must be lint-free, pest-free, flat skin, not stamped, not cracked. For pickling, the type of Kohlrabi is selected with high sugar content, the best is Kohlrabi with a sugar content of 1.5-3%. After buying Kohlrabi, clean the mud on the raw materials, peel off the outer shell, and then wash it several times with water. The Kohlrabi is cleaned and sliced about 8 mM thick. It can then be cut into pieces depending on the size of the glue containing the fermentable sample. Next, blanching process will make the process of compacting Kohlrabi easier and convenient when it comes to packaging. Conditions in this process are at 70 °C, 25 s with 0.5% $CaCl_2$ solution. After blanching, the Kohlrabi pieces are placed in glue containing a brine solution, which has been pasteurized and cooled. The glue is then sealed. This step aims to create anaerobic conditions for lactic fermentation to occur. Note, the salt water solution should cover the Kohlrabi from 3 to 5 cm. In the early stages of fermentation (first 1 to 2 days) there will be air bubbles because the volume of Kohlrabi increases by about 2-3%. This foam layer needs to be removed to ensure that fermentation continues. Lactic fermentation stops when the lactic acid content reaches about 1.5-2.4%, however the product has the best taste when the lactic acid content reaches from 0.8-1.2%. Finally, pickled Kohlrabi products are packed and stored at the right temperature.

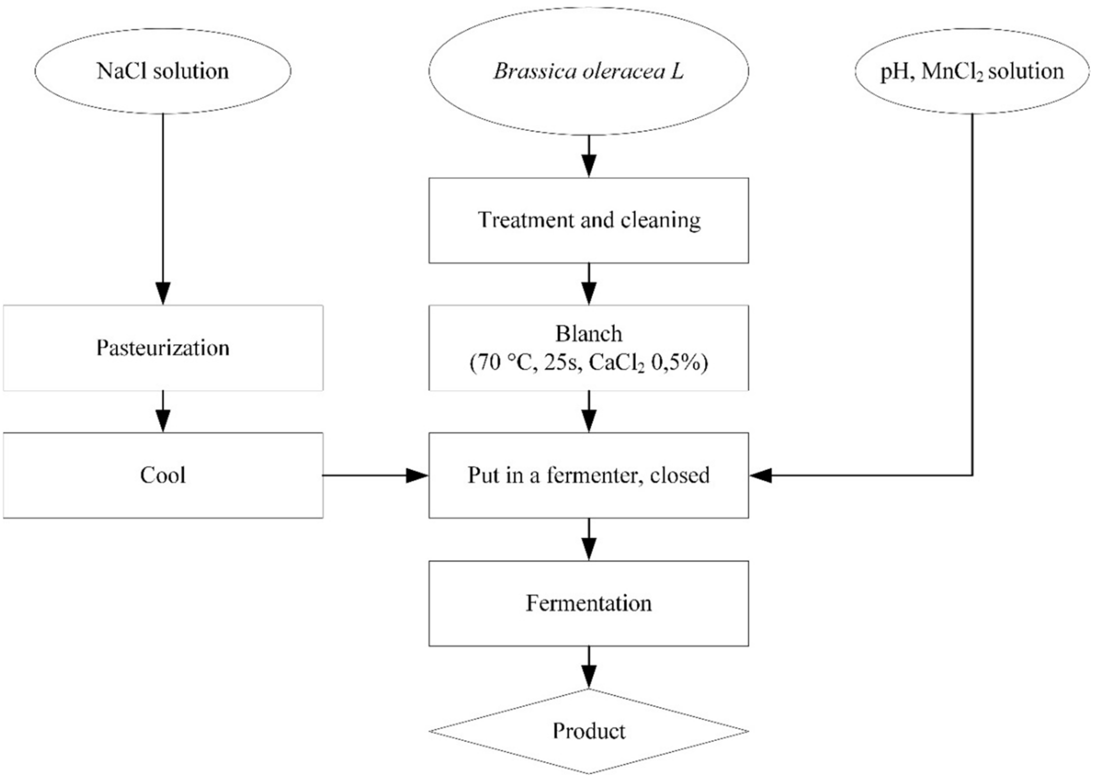

Fig. 1. The process of the Kohlrabi was pickled by Lactic fermentation

Table 1. Analytical indicators

Indicators	Method
pH of solution on fermentation	Use a pH meter.
Acid content (%)	Use standard alkaline solution NaOH (0.1N) to neutralize all acids in food with phenolphthalein solution as color indicator.
Salt content (%)	Based on the Mohr method - use $AgNO_3$ standard solution (0.1N) to react all salts in neutral solution with K_2CrO_4 indicator.
Total sugar content (%)	Based on the Lane-Eynon method. Based on the reaction of the inverse sugar, copper in Fehling's solution is reduced to copper (I) oxide (Cu_2O) with brick red color.
Vitamin C content (mg%)	Based on the Muri method. Titrate with 2.6-dichlorophenol-indophenol.
Structure (stiffness)	Using a Rheotex hardness tester.
Feelings	Using the Hedonic scoring method.
Color	Measure the color of materials and products with a Photoelectric Colorimeter.

Analytical indicators

The analytical criteria for raw materials and products are performed as shown in Table (1).

Sensory evaluation method

Table 2. Description of sensory criteria on taste of pickled Kohlrabi products

Score	Description
5	Characteristic aroma of pickled Sauerkraut, harmonious sour taste
4	Light aroma, slightly sour taste or slightly lacking in sourness, too sour
3	Less aromatic, slightly strange taste, slightly salty
2	Unscented, has a strange taste
1	The smell of broken products

Table 3. Description of structural sensory criteria of the products

Score	Description
5	Evenly crispy
4	A little crispy
3	Slightly soft
2	Soft
1	Much soft

Table 4. Description of sensory evaluation criteria of product preference

Description	Score
Like it so much	9
Like it a lot	8
Like it just right	7
I like it a bit	6
Don't like don't get bored	5
A bit bored	4
Moderately boring	3
Bored a lot	2
Extreme boredom	1

Influencing factors in the lactic fermentation of Kohlrabi

The influencing factors in the lactic acid fermentation process of Kohlrabi performed in this study include investigating the influence of salt solution concentration (2.5-4.0%), the pH value of initial fermentation solution (pH 3.4–6.0), and fixed the content of additional minerals (Mn^{2+}, 30 mM) to the fermentation process and the quality of pickled Kohlrabi. The criteria to evaluate and optimize the conditions include pH value of fermentation solution, time to finish fermentation, date, acid content produced by fermentation (g/L), acid content of product (%), product structure, product color, sensory evaluation: brittleness, taste, color.

Results and discussion

Analysis of ingredients

The amount of fermentable sugar is the main factor affecting the growth of lactic acid bacteria whose purpose is to convert carbohydrates into lactic acid and acetic acid. The results of the lowering of pH depend on the amount of sugar and the type of acid produced as well as the buffering capacity of the fermentable vegetables, from which the minimum amount of fermentable carbohydrates can be determined. Therefore, the analysis of the starting material composition is very necessary. The results of the analysis of the ingredients are shown in Table (5).

Table 5. Ingredients in 100g edible portion of Kohlrabi

Composition	Unit	Value
Total sugar content	%	2.50±0.026
Vitamin C content	mg%	30.65±0.259
Total acid %	% (calculated as lactic acid)	0.162±0.015

According to many domestic and foreign studies, the suitable sugar content for the process of pickling vegetables is 1.5-3.0%. The analysis results show that Kohlrabi has a total sugar content of 2.5%, which is quite suitable for the pickling process and therefore it is not necessary to add sugar from the outside. As with most other plants, the main sugars in Kohlrabi are glucose, fructose, and sucrose. These are very suitable substrates for the metabolism, activity and growth of lactic acid bacteria. During fermentation, there is a decrease in sugar content with fermentation time. This is clearly due to the amylolytic activity of *Lactiplantibacillus plantarum*, some of the starch being converted to sugars and converted to lactic acid in the organic acid metabolism cycle. However, all of the fermentable sugars were not converted to lactic acid, a ratio probably actually used by *Lactiplantibacillus plantarum* and other microorganisms present in the fermentation medium for converting their normalization. Besides, the high vitamin C content in Kohlrabi is an ideal source of vitamin C in the diet. Through the pickling process, under acidic and anaerobic conditions, vitamin C is largely retained, with little loss. In order for the pickling process to create a stable, good quality product, it is necessary to investigate the influence of many factors affecting this processing and preservation process.

Effect of salt concentration on quality of pickled Kohlrabi products

The process of pickling vegetables is affected by many factors; in which salt plays a very important role in the initiation of fermentation, and has a significant impact on the quality of the end product. The use of salt at high concentrations is often the cause of inhibiting the growth of the desired bacteria, although in some cases salt has a positive role in the structure of pickled vegetables. For example, an increase in salt concentration limits the growth of pseudomonads, flavobacteria, and molds while the specific growth of lactic acid bacteria is promoted. On the other hand, too low a salt concentration (<0.8%) can lead to undesirable fermentation as well as poor quality products such as softened products. Therefore, finding an additional salt solution with the right concentration for fermentation will contribute to a stable and good quality product.

Effect of salt concentration on pH value change of fermentation

The Kohlrabi fermentation was carried out with a ratio of Kohlrabi: salt solution of 1:1, in which, the salt solution was investigated at 4 different concentrations, ranging from 2.5, 3, 0, 3.5 and 4.0%. Proceed to stop the fermentation process after 3 days (when the pH of the fermentation solution is between 3.0 and 3.3). The results of the analysis and statistics on the influence of salt concentration on the final pH change of the fermentation solution was presented in Fig. (2).

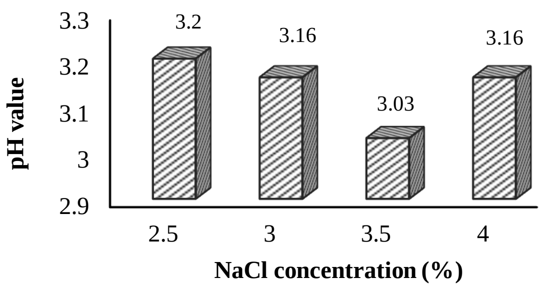

Fig. 2. Change of pH value of fermenter with different salt concentration

From the results as shown in Fig. (2), there is a difference in the pH value of the fermented milk solution corresponding to the salt solutions with different salt concentrations. At low concentrations of NaCl used (2.5 and 3.0%) or higher than the optimum (4.0%) the pH value of the fermenter was higher and significantly different from that of the fermenter. The appropriate salt concentration level, in the case of the survey, is 3.5%. This may be because when Kohlrabi is fermented at low salt concentration, it is not enough to create osmotic pressure for the sugar solution to escape to create a suitable substrate for lactic acid bacteria to grow. In contrast, at a salt concentration of 4.0%, although creating a large osmotic pressure, because this salt concentration is quite high, it inhibits the growth of lactic acid bacteria, resulting in slow fermentation. Therefore, the pH at the end of the fermentation solution was still quite high, significantly different from the fermentation solution at the salt concentration of 3.5%. With a salt concentration of 3.5%, the sugar solution in the raw material is easily released, creating a sufficient substrate for lactic acid bacteria to rapidly reduce the pH of the brine solution from 7.5 to pH to stop the fermentation process. In other words, the efficiency of the fermentation process is optimal with a salt concentration of 3.5%. Besides the pH value, the fermentation process at different salt concentrations also affects other parameters such as acid content in the product, the amount of salt absorbed into the product.

Effect of salt concentration on the acid content of the product

The salt concentration has a significant effect on fermentation as shown by the final pH at which fermentation stops. Not only that, it also indirectly affects the taste of the product through the acid content of the product (Fig. 3). From the results presented in Fig. (3), the following comments can be drawn: Simultaneously with the difference in final pH, the acid content in the product is also different. The lower the pH value of the fermentation broth, the higher the acid content of the product. At a salt concentration of 2.5%, the lowest acid produced corresponds to the highest final pH. The highest amount of acid produced corresponds to a salt concentration of 3.5%. Thus, the lower the pH of the fermentation process with salt solution, the higher the acid content produced in the product, quickly achieving the appropriate product taste.

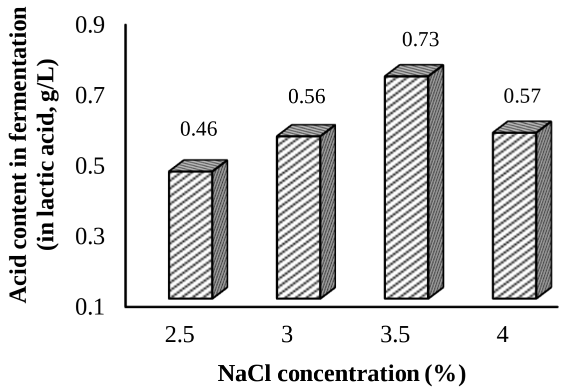

Fig. 3. Effect of salt concentration on the acid content of the product

Effect of salt concentration on the amount of salt absorbed into the product

The fermentation process of Kohlrabi as well as pickled vegetable products is carried out by means of a salt solution creating osmotic pressure, allowing nutrients and water in the raw materials to diffuse into the environment, creating a substrate for lactic acid bacteria work. At the same time, salt also seeps into the Kohlrabi, affecting the taste of the end product. The salt content infiltrated into the product according to the levels of salt used in the fermentation solution is shown in Fig. (4). Accordingly, the higher the salt concentration in the fermentation medium, the higher the salt content of the product will be after fermentation. This result is statistically different. However, the salt content in the product affects the sensory value, too high or too low salt concentration affects the taste of the product.

At the salt concentration of 2.5%, the salt content infiltrated into the product is the lowest, corresponding to the lowest acid content, so it cannot create the typical salty taste of salted pickled vegetables. However, at a salt concentration of 4%, the salt content infiltrated into the product was high, causing a clear salty taste to the product. Thus, to be able to choose the appropriate salt concentration for the fermentation of Kohlrabi with high quality, the sensory values and especially the structure of the product need to be taken into consideration.

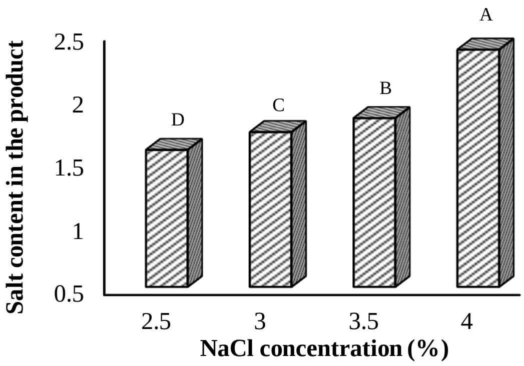

Fig. 4. Effect of salt concentration on the amount of salt absorbed into the products
Different letters in the same column represent a significant difference at the 95% confidence level.

Effect of salt concentration of fermentation on the change of product texture

The texture of Kohlrabi-expressed in terms of brittleness, is one of the important quality parameters of Kohlrabi pickled. Improper fermentation can cause the product to lose its characteristic brittleness. In addition, the addition of $CaCl_2$ to the fermented brine reduced the concentration of NaCl required to maintain the structural properties of pickled cucumbers. Therefore, the evaluation of the effect of fermentation at different salt concentrations on the brittleness of the product was made based on comparing the change in the product hardness value (H) with the hardness value. Measured hardness of the raw material before fermentation (H_0), the results are summarized as shown in Fig. (5). The results obtained in Fig. (5) show that, after the appropriate fermentation time, the structure of the product obtained with different fermentation salt concentrations is significantly different. The texture of the product is influenced by the moisture content of the product. At the same time, the structure is also affected by the fermentation time. At a low salt concentration of 2.5%, the osmotic pressure is small, the fermentation process is slower, and the brittleness of the product is reduced. However, thanks to the slow diffusion process at low salt concentration, the nutrients and moisture of Kohlrabi slowly escape into the environment resulting in a Kohlrabi structure remaining intact. Stronger hardware (H/H_0= 0.93±0.035) when compared to fermented products with a salt concentration of 4.0% (H/H_0= 0.75±0.091). This suggests that high salt concentration is responsible for accelerating the osmotic process, leading to structural destruction of plant cells. On the other hand, the structure of pickled vegetables is affected by salt infiltration into the cell structure, causing changes in the pectin structure. Along with the decrease in pH at the end of fermentation from 3.20 to 3.03, corresponding to an increase in salt concentration from 2.5% to 3.5%, there was an increase in structure. The reason may be due to the increase in salt concentration to 3.5%, resulting in a decrease in the fermentation time to reach the required pH, shortening the soaking time in the fermentation solution, and reducing the loss of structure.

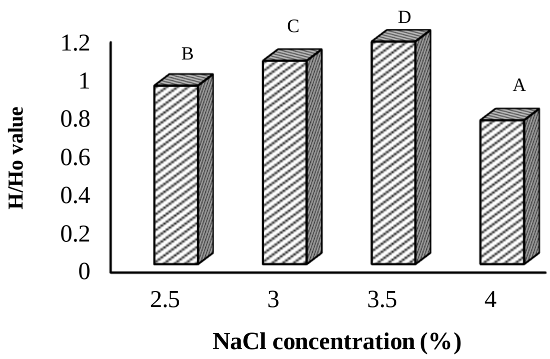

Fig. 5. Effect of salt concentration of fermentation on the change of products structure
Different letters in the same column represent a significant difference at the 95% confidence level.

Effect of salt concentration on the sensory value of the product

The end product of conventional fermentation is lactic acid with lesser amounts of acetic acid and propionic acid, a gaseous mixture with CO_2 as the predominant gas, a small amount of alcohol, and a mixture of aromatic esters. Acids combine with alcohol to form esters, contributing to the characteristic taste of pickled Kohlrabi. The product has stable quality, but whether it is accepted or not depends on the perception of the consumer. The salt content used affects not only the formation of anaerobic conditions, the type and persistence of microbial growth, but also the organoleptic properties of the end product. Therefore, sensory evaluation is also a criterion to choose the optimal value to both ensure quality and suit everyone's taste. The results of sensory evaluation of the product in terms of taste, brittleness and preference are shown in Fig. (6). The sensory evaluation results showed that the sample with 3.5% salt concentration gave the highest sensory scores for brittleness, taste and preference and was significantly different from the rest of the samples. In terms of taste, the sample fermented in a solution of salt concentration of 2.5% gives the product a slightly bland taste and strange taste because this salt concentration has not yet inhibited the growth of foreign microorganisms. In a solution of 4% salt concentration, the product has a slightly salty taste due to the high salt content. The salt concentration of 3.5% gives the product a harmonious taste, characteristic of sour salt products and significantly different from the remaining salt concentrations.

Although the values of structure and taste are important parameters determining the final quality of pickled products, however, color is an external factor that has a great influence on the evaluation of the consumer choice for the product. Therefore, color is also one of the quality parameters that need attention.

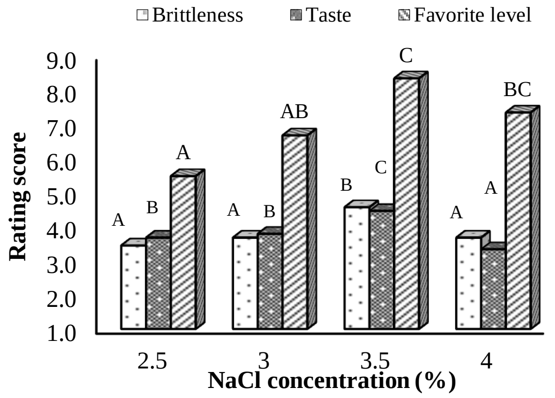

Fig. 6. Effect of salt concentration on the sensory value of the product
Different letters in the same column represent a significant difference at the 95% confidence level.

Effect of salt concentration on the color change of pickled Kohlrabi

During Kohlrabi fermentation, the formation of lactic acid changes the product pH, which leads to a change in the color of pigments, especially chlorophyll. The color of vegetables changes from light green to yellow green or olive due to the interaction of acid and chlorophyll, and the white color of Kohlrabi meat also changes to waxy translucent shade due to the withdrawal of air from cells. Therefore, the change in brightness (expressed in L value) and whiteness index (WI) of fermented Kohlrabi should be considered. The results are measured and statistical with 95% confidence, summarized in Fig. (7).

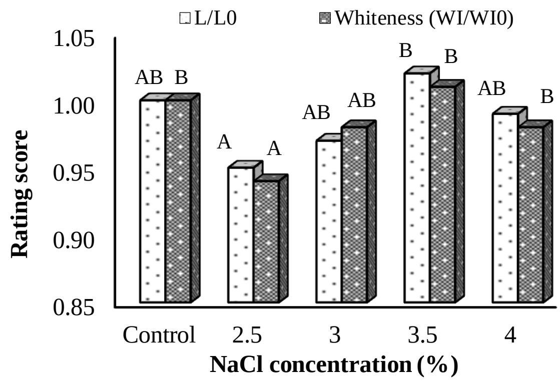

Fig. 7. Effect of salt concentration on the color change of pickled Kohlrabi
Different letters in the same column represent a significant difference at the 95% confidence level.

Statistical results in Fig. (7) show that the brightness L of Kohlrabi is often reduced compared to the raw materials before fermentation, shown in the L/L_o ratio, which is less than 1, except in the case of products. The product was fermented in a 3.5% saline solution. However, the change in color brightness of the product according to the salt concentration of the fermenter did not have a statistically significant difference.

Corresponding to samples fermented in a solution with salt concentration of 3.5%, the highest acid content was produced (corresponding to the lowest pH), causing the fastest color loss of chlorophyll, making the color and brightness of the sample increase, so the L/L_o and WI/WI_o ratios are slightly larger than other samples. Thus, the fermentation process at a concentration of 3.5% salt solution was selected as the optimal parameter for processing pickled Kohlrabi products.

Effect of pH value on quality of pickled Kohlrabi products

The pH value is a factor that significantly affects the growth of different groups of lactic acid bacteria. For example, homomorphic lactic acid bacteria grow well at pH 3.8-4, while cocci cannot grow in this medium. At the same time, pH is a decisive factor in the formation of odor and taste of fermented fruits and vegetables (Liu, 2003; Montet, Loiseau, & Zakhia-Rozis, 2006). Most lactic acid bacteria favor near-neutral pH conditions (Battcock & Azam-Ali, 1998; Demain, 2000). The optimum pH of fermented vegetables such as Sauerkraut and Kimchi has been reported to be around 3.5-4.5 (Gardner, Savard, Obermeier, Caldwell, & Champagne, 2001; Montet *et al.*, 2006). On the other hand, Fleming (1984) showed that the initial acidification of brine inhibited acid-sensitive bacteria and was suitable for the growth of lactic acid bacteria. Therefore, finding a suitable initial fermentation pH for fermentation will contribute to the creation of a stable and good quality product. According to previous studies, the suitable pH for sour bacteria was generally around 3.0-4.5. However, through testing, it was found that pH 3.0 often had the appearance of mold, and some lactic acid bacteria had the best fermentative activity in the pH 5.5-6.0 region. Therefore, studying the effect of pH of the initial fermentation solution, the experiment was arranged with variable values in the range from 3.4 to 6.0. The results are evaluated based on the change in the properties of the raw materials and the environment (fermentation fluid).

The criteria for choosing the optimal pH value were made by the acid content of fermentation (calculated in lactic acid, g/L), the acid content in the product, (in % lactic acid), the structure (H/H_o), sensory value (brittleness, taste, favorite), and color (L/L_0, WI/WI_0) of the product.

The results as shown in Fig. (8) show that the acid content produced by the fermentation process was the highest (7.66 g/L) at the initial pH value of 4.2. As for the initial pH value of 3.4, the produced acid content was the lowest compared to the. This may be due to the delay in acid formation during fermentation as the high content of acetic acid was added to the mixture. As the initial pH value increased from 4.6 to 6.0, there was a gradual decrease in the acid content produced by fermentation. This is because the further away from the optimum pH value, the lower the amount of acid produced. The rapid decrease in pH is important for the quality of the final product (Viander, Mäki, & Palva, 2003). Hardness and brittleness are the main characteristics influencing consumer acceptance of pickles. As mentioned, the structure of the product is influenced by the moisture content of the product and also by the fermentation time. According to Fleming (1984), acetic acid had no significant effect on hardness. Therefore, the difference in H/H_0 ratio in this experiment could be due to the difference in fermentation rate, leading to the difference in the fermentation time to reduce the pH to the appropriate value. Corresponding to the initial pH value of 4.2, the H/H_o ratio was found to be the highest and significantly different from other initial pH values.

In addition, the sensory evaluation results (Fig. 8D) showed that the sample with the initial pH value of 4.2 gave the highest sensory scores for brittleness, taste, favorite, and was significantly different from that of the sample. In terms of taste, samples with a value of pH 3.4 or 3.8 resulted in the product with a very acidic taste, whereas the medium at pH 5.0-6.0 promoted the product with a slightly less acidic taste. The pH 4.2 value gave the product with a relatively harmonious taste-a characteristic sensorial property of sour salt products. Finally, the brittleness (L) value of Kohlrabi was usually reduced compared to the pre-fermentation material, as shown in the L/L_0 ratio which was less than one. L/L_0 and WI/WI_0 ratios responses to different initial pH values were statistically significant. This shows that the added acetic acid and lactic acid produced by fermentation have significantly changed the L, a, and b index of Kohlrabi. For the sample with an initial pH of 4.2, due to the high content of acid produced, it led to a large change in chlorophyll, so the product had a higher brightness than other samples.

Thus, the fermentation process with an initial pH value of 4.2 was selected as the optimal parameter for processing pickled Kohlrabi products.

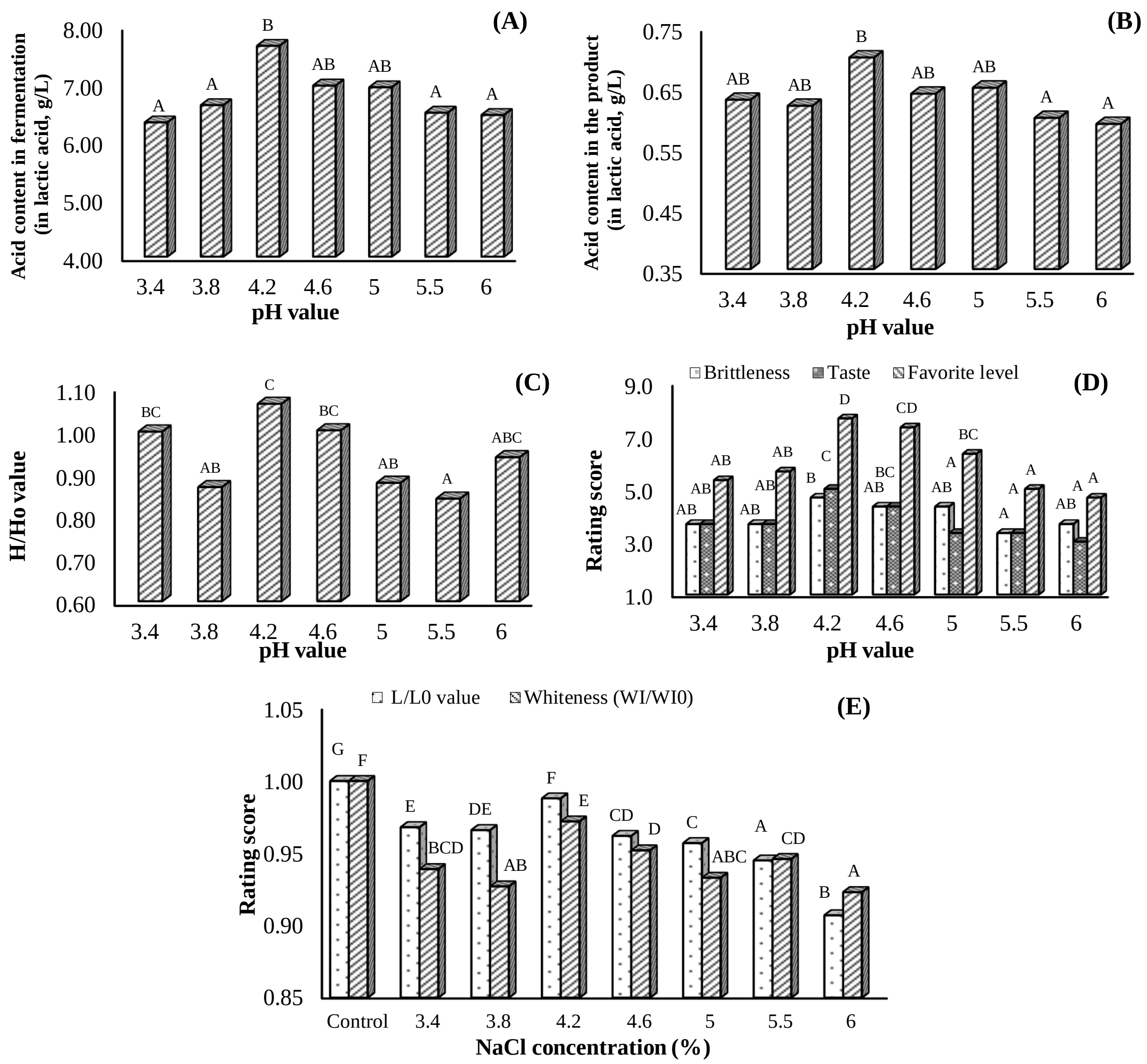

Fig. 8. Effect of pH value on quality of pickled Kohlrabi products
Different letters in the same column represent a significant difference at the 95% confidence level.

Conclusions

The pickled Kohlrabi is a product processed by natural lactic fermentation by lactic bacteria available on raw materials or the external environment. From the results obtained through the implementation in this study, on the basis of data analysis and statistics, it can be said that the optimization of the pickled Kohlrabi process should be carried out according to conditions such as the initial concentration of the salt solution used is 3.5%, the fermentation is carried out with the initial pH of the fermenting solution pH 4.2, the mineral $MnCl_2$ with a concentration of 30 mM is added to the fermentation solution to obtain Kohlrabi pickle products have good quality and sensory scores after 2 days of fermentation at room temperature. Besides, temperature is a factor that directly affects the growth of lactic acid bacteria. However, low temperature fermentation will prolong the fermentation time, leading to loss of hardness, quality loss and being uneconomical.

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تأثیر غلظت نمک و مقدار pH روی فرایند تخمیر کلم قمری (*Brassica oleracea* L.)

ترن سین هین[1و2]، ترن سن تراک[3و4]، نگوین ون مووی[3*]

1- دانش‌آموختهٔ کارشناسی ارشد، دانشکده مهندسی مواد غذایی و محیط زیست، دانشگاه نگوین تات تان، شهر هوشی‌مین 700000، ویتنام

2- دانش‌آموختهٔ کارشناسی ارشد، مؤسسه مهندسی محیط زیست، دانشگاه نگوین تات تان، شهر هوشی‌مین 700000، ویتنام

3- دانشیار، کالج کشاورزی، دانشگاه کان‌تو، شهر کان‌تو 94000، ویتنام

4- دانشیار، مدرسه تحصیلات تکمیلی، دانشگاه کان‌تو، شهر کان‌تو 94000، ویتنام

5-استاد، کالج کشاورزی، دانشگاه کان‌تو، شهر کان‌تو 94000، ویتنام

* نویسندهٔ مسئول (nvmuoi@ctu.edu.vn)

چکیده

سبزیجات می‌توانند مواد مغذی ازجمله ویتامین‌ها، مواد معدنی و به‌ویژه فیبر را فراهم کنند و سمومی را که در طول هضم غذا ایجاد می‌شوند، آزاد کنند. درنتیجه اهمیت سبزیجات در رژیم غذایی انسان به‌طور فزاینده‌ای مورد تأکید قرار گرفته است. در این تحقیق از کلم قمری، سبزی غنی از ویتامین C برای تخمیر لاکتیک استفاده شد. تمام فرایند با تغییر طیف وسیعی از پارامترها ازجمله غلظت محلول نمک و مقدار pH روی رشد باکتری‌های اسید لاکتیک، بافت محصول و ویژگی‌های حسی بهینه‌سازی شد. نتایج این تحقیق شرایط بهینه برای فرایند تخمیر در استفاده از محلول NaCl به میزان 3/5 درصد از مقدار pH اولیه 4/2 و MnCl2 با غلظت 30 میلی‌مولار را نشان داد. محصولات ترشی کلم قمری به‌دست‌آمده پس از 2 روز کیفیت قابل‌قبول و امتیاز حسی خوبی از خود نشان دادند. همچنین مشخص شد که دمای بالا با ازدست‌دادن سختی، کاهش کیفیت و زمان تخمیر طولانی‌تر همراه است. فرایند ترشی کلم قمری بهینه با تنوع بخشیدن به محصولات ترشی کمک می‌کند تا از عیوب ناشی از فراوری نامناسب جلوگیری شود.

واژه‌های کلیدی: تخمیر لاکتیکی، کلم قمری (*Brassica oleracea* L.)، محتوای نمک، ویتامین C