ABSTRACT
In this study, antioxidant properties and enzymatic activities during fermentation of Kiwifruit from two Actinidia genotypes were evaluated. The samples were evaluated for solid content (SSC), total phenols, superoxide dismutase (SOD) and protease. Antioxidant capacity was determined using four assays: 2,2-diphenyl-1-picrylhydrazyl (DPPH), 2,2‘-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS), hydroxyl radical (HR) scavenging rate and superoxide anion radical (SAR) scavenging rate. In the process of fermentation, the antioxidant and enzyme activities of artificial fermentation kiwifruit products were significantly higher than those of natural fermentation (p < .05). At the end of fermentation, the contents of total phenols and SSC in the fermented products of Hongyang kiwi fermentation (HKF) group and Cuiyu kiwi fermentation (CKF) group were significantly decreased, while the antioxidant properties of DPPH, ABTS, HR and SAR were significantly increased compared with the fresh kiwi (p < .05). In addition, the content of protease and superoxide dismutase was also increased. It was also found that the antioxidant properties and the enzyme activities in the HKF group were higher than those in the CKF group. ABTS and SOD activities were more obvious, which were 1.42 times and 2.22 times of the CKF, respectively. HKF group showed better nutritional properties and biological activities.

KEYWORDS
Hongyang kiwifruit; antioxidant properties; enzyme activities

INTRODUCTION
Kiwifruit originated from China, and it is one of the most popular fruits in the world because of its flavors and health benefits (Wu et al., 2019). Currently, there are many different Actinidia genotypes of kiwifruit commercially grown in China, including ‘Hongyang’ (A. chinensis), ‘Cuiyu’ (A. chinensis), ‘AnminR1’ (A. arguta), ‘AnminG2’ (A. kolomikta), ‘Hayward’ (A. delicosa) (Wang et al., 2018) and other varieties, which are mainly distributed in Sichuan, Chongqing, Guizhou, Shanxi and Zhejiang provinces (Figure 1). Hongyang kiwi, also known as ‘Red sun’ kiwi, is a rare and excellent species selected from wild kiwi variety by the Sichuan Natural Resources Research Institute of China. The flesh of Hongyang kiwi is green yellow to yellow, circle of red around white core (Figure 1). Kiwifruit is a seasonal fruit, although low-temperature storage can improve the shelf life, the flavors and nutrition will change (Park et al., 2013; Richardson et al., 2018); therefore, the development of deep-processed products of kiwifruit can broaden its consumption and preservation methods.

Fermentation is not only good for prolonging the shelf-life of foods (Septembre-Malaterre et al., 2018) but also beneficial for improving the biological activity and nutritional properties of products,

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such as trace minerals, vitamins, amino acids, enzyme and antioxidants (Di Cagno et al., 2013). Fermentation strains play an essential role by converting sugars from the fruit/vegetable into ethanol, carbon dioxide or other by-products (Liu et al., 2017). Fruit and vegetable fermentation is divided into spontaneous fermentation and inoculation fermentation (Szutowska, 2020). Spontaneous fermentation mainly relies on fruits and the dominant bacterial community in the natural environment for fermentation. Its quality and flavors are closer to the fruit itself, but the fermentation efficiency is not high and the quality is difficult to control. Inoculation fermentation is a fermentation with one or more microorganisms as the starter, which can effectively improve the fermentation efficiency and control the process (Tamang et al., 2020). Recently, studies have found that lactic acid bacteria (LAB) are probiotics that can convert sugar into lactic acid and provide nutrition (Eş et al., 2018).

LAB fermentation food has a long history. In recent years, more and more attention focused on fruit and vegetable juice as a matrix of yeast-LAB fermentation. There is a mutualistic growth and metabolism relationship between yeast and lactobacillus in mixed culture and fermentation (Wang et al., 2019). In the process of fermentation, LAB metabolize lactic acid to form a weak acidic growth environment, on the one hand, to inhibit the growth of spoilage bacteria such as Bacillus subtilis and Escherichia coli and, on the other hand, to provide a suitable acidic environment for yeast growth. During the fermentation process, yeast not only produces protease, decomposing the protein in the substrate, but also secretes nutrients such as amino acids, vitamins and other nutrients, which provides a good growth environment for LAB and promotes the rapid growth of LAB (Li et al., 2020). Therefore, yeast-LAB fermentation has become a research hotspot of fruit and vegetable fermentation. At present, the international market of fermented products has a vast space for development, especially for low alcohol wine alternative beverage products (Choi et al., 2015). In terms of fermented kiwifruits, previous researches mainly focused on the fermentation of pure kiwi juice (Liu et al., 2020), and there are few studies on the kiwifruit pomace fermentation.

The purpose of this study was to explore fermented kiwifruit as functional product for food industry applications. Therefore, the primary aim of this study is to investigate the changes of total phenols (TP), antioxidant properties and enzyme activities in the whole Hongyang kiwi fermentation cycle by comparing with Cuiyu kiwi (green pulp fresh), the common kiwi consumption in China market. Another objective was to compare changes in the activity of artificially and naturally fermented kiwi. It is expected that these results will provide a better understanding of fermentation
about Hongyang kiwi and provide a theoretical and scientific basis for further improving the fermentation technology of Hongyang kiwi.

**Materials and Methods**

**Chemicals and Reagents**

*Saccharomyces cerevisiae* was purchased from Sofralab (Sofralab the Enological Co., France). *Lactobacillus bulgaricus* and *Streptococcus thermophilus* were obtained from Chuanxiu (Chuanxiu Technology Company, Beijing, China), pectinase was purchased from Pangbo (Pangbo Enzyme Company, Nanjing, China), cellulase was purchased from Heshibi (Heshibi Biotechnology Company, Ningxia, China), food-grade citric acid was obtained from Wanbang (Wanbang Industrial Co., Henan, China), salicylic acid, Folin-ciocalteu reagent, sodium carbonate, 2,2-diphenyl-1-picrylhydrazyl radical (DPPH), 2,2′-azinobis-(3-ethylbenzothiazoline)-6-sulfonic acid radical (ABTS), 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox), absolute ethanol, potassium persulphate, Tris-HCl, phosphate buffer, trichloroacetic acid, H₂O₂ solution, HCl, pyrocatechol, distilled water, deionized water and potassium ferricyanide were purchased from Chuandong (Chuandong Chemical Industry Group Co., Chongqing, China).

**Sample Collection and Preparation**

Hongyang kiwi was collected from Zouma town of Wanzhou, Chongqing, China. The sample was identified by the Northeast Chongqing Special Biological Resources Development and Utilization Engineering Center. Cuiyu kiwi was purchased from local supermarket. The fruits were immediately transported to the laboratory within an hour and stored in controlled atmosphere storage (4°C, 3–5% O₂ + 3–4% CO₂). Cuiyu kiwi was purchased from Yonghui supermarket in Chongqing.

Kiwi with a complete hardness of 0.5–1.0 kg/cm² was selected. After it was washed and dried, kiwi was cut into pieces with skin and put into an aseptic fermentation tank (10 L). The amount of sterilized water was mixed with kiwi in a ratio of 1:1.5. Then, the addition amount of yeast, lactobacillus, pectinase, cellulase and sucrose was added 1.0, 0.4, 0.4, 1.0 and 20%, respectively. The pH (3.52) was adjusted with citric acid and fully stirred. The fermentation temperature was 36°C, and the fermentation was conducted for 21 days. The sampling time of kiwi fermentation broth starts from the third day of fermentation and samples were taken every 3 days.

The experiment was carried out in four groups: Hongyang kiwi fermentation group (HKF), Cuiyu kiwi fermentation group (CKF), natural environment without adding bacteria and enzymes fermentation for Hongyang kiwi (NHKF) and natural environment fermentation for Cuiyu kiwi (NCKF).

**Soluble Solids Content (SSC) Determination**

The fermentation supernatant was absorbed and centrifuged at 3000 × g at room temperature for 15 min (Centrifuge 5430R, Eppendorf). Then, the SSC was measured by utilizing refractometer at 25°C (Tilahun et al., 2020). One to two drops of kiwi supernatant were added into a digital PAL-BX refractometer (ATAGO, Tokyo, Japan) to read SSC.

**Extractive Procedure of Extracts from Samples of Fermented Kiwi**

Extractive procedure was based on the method by Ma (Ma et al., 2019) with slight modification. Thirty grams of fermented kiwi was weighed and diluted with methanol-water (80:20, v/v). The mixtures were then blended at 10,000 × g for 1 min. The mixed solution was shaken overnight at 150 rpm at 20°C. The fermented kiwi extracts were centrifuged at 3000 × g for 20 min at 4°C and supernatants were analyzed for next stage.
**Total Phenols, Activity of Protease and Activity of Superoxide Dismutase**

TP were determined using Folin-Ciocalteu colorimetric method. A total of 2 mL of Folin-Ciocalteu reagent was added to 1 mL diluted supernatant (1:9 v/v). After 3 min, 2 mL of 10% Na₂CO₃ was added, followed by distilled water in a final volume of 25 mL. The mixture was shaken and allowed to rest for 1 h in dark at 25°C. The absorbance of all mixtures was measured at 760 nm using a UV-Vis spectrophotometer (UV-2450, Shimazu Corporation, Kyoto, Japan). The results were expressed as mg gallic acid equivalents (GAE)/100 g FW ± SD.

The enzymatic activity of protease was measured indirectly by the colorimetric reaction of protease decomposition of casein (substrate) to produce phenolic amino acids (Lei et al., 2016). One milliliter of 1% tyrosine solution and 1 mL supernatant were preheated for 5 min at 40°C and then reacted in a test tube with water bath at 40°C for 10 min. Two milliliters of 0.4 mol/L trichloroacetic acid was immediately added successively. It stood for 10 min and was filtered with slow qualitative filter paper. One milliliter of filtrate was successively added with 5 mL Na₂CO₃ solution and 1 mL Folin-Ciocalteu reagent, and the absorbance value was measured at 680 nm after 20 min in a water bath at 40°C. Total protease activity was expressed in units (U/100 g FW ± SD).

Activity of superoxide dismutase (SOD) was determined by the pyrogallol autoxidation method with slight modification (Li, 2012). Two milliliters of carbonate buffer (pH 8.0) was mixed with 200 μL of supernatant sample and 50 μL pyrogallol (60 mM in 1 mM HCl, 37°C) and then shaken rapidly at 37°C. The rate of sample autoxidation was observed by monitoring the increase in absorbance at 325 nm every 30 s for 240 s. The inhibition rate of the sample on the autoxidation rate of pyrogallol reflects the content of SOD in the sample. Total SOD activity was expressed in units (U/100 g FW ± SD).

**DPPH· Radical Scavenging Rate**

The DPPH· radical scavenging rate was conducted according to the Kim’s method (Kim et al., 2019) with slight modification. Three clean test tubes were prepared and numbered. Then, 1.6 mL deionized water was added into test tube 1, while 0.5 mL extracts of fermented kiwi and 1.1 mL deionized water were added into test tube 2 and test tube 3, respectively. Then, 2.1 mL 0.1 mmol/L DPPH ethanol solution was added into test tube 1 and test tube 2, respectively, and 2.1 mL anhydrous ethanol was added to test tube 3. All of the three test tubes reacted at 25°C in the absence of light for 60 min. Then, the absorbance was measured at 517 nm. Results were expressed as μmol trolox/100 g FW ± SD. The formula for the scavenging rate as follows:

\[ \text{DPPH scavenging rate}_\% = \left[ 1 - \frac{A_1 - A_3}{A_2} \right] \times 100\% \]  

(1)

(where \( A_1 \) is the absorbance of the reactants in the test tube 1, \( A_2 \) is the absorbance of the reactants in the test tube 2, \( A_3 \) is the absorbance of the reactants in the test tube 3.)

**ABTS·+ Radical Scavenging Rate**

The determination of ABTS+ scavenging rate was based on the method used by Re (Re et al., 1999). ABTS·+ was generated by reacting 5 mL 7.0 mM ABTS stock solution with 88 μL 2.6 mM K₃C₅O₆ and left for 12–16 h in dark. Then, ABTS·+ working solution was obtained by dilution with PBS (5 mM phosphate buffered saline, pH 7.4) to an absorbance of 0.70 ± 0.02 at 734 nm. Subsequently, 0.2 mL of working solution was added to 10 μL extracts of fermented kiwi at 25°C and left for 6 min in the dark. Then, the absorbance was measured at 734 nm. Results are expressed as μmol trolox/100 g FW ± SD.

The formula for the scavenging rate is as follows:
\[ \text{ABTS}^+ \text{scavenging rate} \% = 1 - \frac{A_1}{A_2} \times 100\% \]  

(where \( A_1 \) is the absorbance measured sample solution. \( A_2 \) denotes the absorbance without the sample solution.)

**Hydroxyl Radical Scavenging Rate**

The hydroxyl radical (HR) scavenging rate was generated by the salicylic acid method with slight modification (Su et al., 2009). One milliliter extract of fermented kiwi was mixed with 1 mL 9 mM FeSO\(_4\) solution and 1 mL 8.8 mM \( \text{H}_2\text{O}_2\), evenly mixed, was placed for 10 min. Then, 1 mL 9 mM salicylic acid was added and the mixture was incubated at 37°C for 30 min. The absorbance was measured at 510 nm. Results were expressed as \( \mu \text{mol trolox/100 g FW} \pm \text{SD}. \) The scavenging activity of extracts was calculated by the following equation:

\[ \text{HR scavenging rate} \% = \left[ 1 - \frac{A_1 - A_2}{A_3} \right] \times 100\% \]  

(where \( A_1 \) is the absorbance-measured sample solution. \( A_2 \) is \( \text{H}_2\text{O}_2 \) replaced by 1 mL distilled water, and the absorbance of the solution is measured as the control. \( A_3 \) is sample replaced by distilled water, and the absorbance of the solution is measured as the blank.)

**Superoxide Anion Radical Scavenging Rate**

Superoxide anion radical (SAR) scavenging rate was determined according to the method of Nie (Nie et al., 2017) with slight modification. Two-point five milliliter extracts of fermented kiwi was mixed with 4 mL 0.05 M Tris-HCL (pH 8.2) buffer solution in the test tube. The mixture was placed at 25°C water bath for 20 min, and then 1.0 mL 2.5 mM pyrogallol was added in the test tube and mixed evenly to make them react properly at 25°C constant water bath for 5 min. The reaction was then immediately stopped with 2 drops of HCl (10 M). The absorbance was measured at 320 nm. Results were expressed as \( \mu \text{mol trolox/100 g FW} \pm \text{SD}. \) The formula for the scavenging rate is as follows:

\[ \text{SAR scavenging rate} \% = \left[ 1 - \frac{A_1 - A_2}{A_3} \right] \times 100\% \]  

(where \( A_1 \) is the absorbance-measured sample solution. \( A_2 \) is pyrogallol replaced by 1 mL distilled water, and the absorbance of the solution is measured as the control. \( A_3 \) is the sample replaced by distilled water, and the absorbance of the solution is measured as the blank.)

**Statistical Analysis**

Each treatment was repeated three times and the results were expressed as ‘X ± SD.’ SPSS Version 16.0 (SPSS Inc., Chicago, USA) was used for significance analysis, and GraphPad Prism 8.0.1 (GraphPad Software LLC, San Diego, USA) was used for graph.

**Results and Discussion**

**SSC and TP**

SSC refers to all compounds dissolved in water in liquid of fluid food. It is an important integrated index to evaluate the quality of fermented products (Giuggioli et al., 2019). As shown in Figure 1, the SSC of fresh Hongyang and Cuiyu were 20.89 ± 0.06 and 18.32 ± 0.06, respectively, which were higher than those in the previous reports (Huang et al., 2017). The SSC in all groups during the fermentation
was significantly lower than that of fresh kiwifruit. The SSC in HKF group increased from 10.63% to 11.68% during the fermentation time, with an average of 11.15% and CKF group increased from 6.67% to 7.80%, with an average of 7.37% (Figure 2a). The SSC in natural fermentation group was significantly lower than that in HKF and CKF groups (p < .05). One reason is that the artificially added yeast and lactobacillus play an active role in fermentation. Among the different fermented groups, HKF group showed the highest SSC. This indicated that the artificial addition of strains and enzymes is helpful to increase the SSC in fermentation.

Many studies have shown that phytochemicals, especially TP, are good resources of natural antioxidants (Ma et al., 2017). Kiwifruit is also a good source of TP (Wojdylo et al., 2017). Previous study reported that the TP content of fresh fruit of Hongyang kiwi and Cuiyu kiwi was 83–87 mg GAE/100 g FW and it was similar to our research (Wang et al., 2018). The content of TP of HKF group...
decreased from 48.27 to 45.74 mg GAE/100 g FW obviously during fermentation (Figure 2b). The content of TP in HKF group and NHKF group showed the similar downward trend during fermentation period and there was significant difference on the third day of fermentation ($p < .05$). The content of TP in CKF group and NCKF group showed the similar downward trend and there was significant difference on the 6th day of fermentation ($p < .05$). The TP content of CKF group decreased from 43.39% to 33.05%. HKF group had the highest TP content, whereas the NCKF had the lowest content.

Fresh fruit has higher SSC and TP than processed fruit products (Sun et al., 2015). Fermentation induces the structural breakdown of plant cell walls, leading to the liberation or synthesis of various compounds, which could augment some of the active ingredients (Kaprasob et al., 2017). The nutrition and function of kiwifruit during fermentation are constantly changing due to the activities of microorganisms and enzyme. In this study, the content of SSC and TP of kiwifruit after fermentation were significantly lower than those of fresh fruit. The results showed that the content of SSC of HKF group was higher than that of CKF group, but the change of SSC of kiwifruit was very different during fermentation, which is maybe related to the composition and SSC in kiwifruit. Soluble polysaccharide is the main component of SSC (Wang et al., 2021). The sugar content of Cuiyu kiwi is higher than that of Hongyang kiwi, while other components such as flavonoids and anthocyanins are lower than that of Hongyang kiwi (Leonotowicz et al., 2016). Thus, polysaccharides were used as the main carbon source in the fermentation process, which significantly reduced the SSC in the fermentation process. At the same time, the enzymatic treatment can significantly increase the total phenolic content in the fermentation broth, which in consistent with Markkinen’s study (Markkinen et al., 2019).

**Antioxidant Activities**

Plants have always been considered to have positive effects on human health, and the related antioxidant activities and the mechanisms of antioxidative activities could be augmented by suitable fermentation technology (Hur et al., 2014). Pharmacological study showed that kiwifruit extracts exert obvious antioxidant activities by in vitro and in vivo assays (He et al., 2019). Therefore, antioxidant properties of extracting solution extracted from fermented kiwifruits were investigated and compared. The DPPH- radical scavenging rate, ABTS$^-$ radical scavenging rate, SAR radical scavenging rate and HR radical scavenging rate from fermented kiwifruit groups are shown in Figure 3. Results showed that the antioxidant properties of all groups increased with the extension of fermented time and HKF group exhibited remarkable antioxidant properties. As shown in Figure 3a, the DPPH values of HKF group ranged from 692.33 to 846.63 μmol trolox/100 g FW. The ABTS values ranged from 702.33 to 808.97 μmol trolox/100 g FW Figure 3b. The results were higher than those in the previous report (Ma et al., 2017), which determined the value of DPPH- and ABTS$^-$ of Hongyang kiwi wine. The reason for this might be the whole fruit fermentation was used in this study, which contains more antioxidant active components. The SAR value of HKF group ranged from 759.97 to 808.97 μmol trolox/100 g FW trolox and the HR value ranged from 561.67 to 943.27 μmol trolox/100 g FW (Figure 3c and d).

In the past, people primarily used fermentation to preserve foods and improve flavors. Fermented products are not only becoming an important part of the diet but also represent local customs and culture (Sanlier et al., 2019). Fermented products are associated with health and nutrition over time. Because of this, the fermentation process and function characteristics of products have recently attracted scientific interest. This study found that although the TP in each group was lower than that of fresh kiwifruit, the antioxidant effect was significantly enhanced, and the antioxidant effect of HKF group was higher than that of CKF group at each fermentation stage. In general, the antioxidant activities of DPPH-, ABTS$^-$, SAR and HR of HKF group were 1.02, 1.42, 1.02 and 1.15 times of those of CKF group, respectively, and ABTS+ and the most obvious antioxidant effect. That might be due to the fact that kiwifruit was immersed with pomace for a long period of time, and fermented strains might have metabolized substances with higher antioxidant properties. After fermentation, the
contents of SSC and TP were decreased, and the antioxidant capacity was improved, which was consistent with the results of Hashemi (Hashemi et al., 2017).

**Enzyme Activities**

Functional enzyme is one of the main active substances in fruit fermentation. For example, protease can hydrolyze protein peptide chain, and thus protein extracted from food can be decomposed by protease in the body, and the amino acids are easily absorbed, which means the absorption of nutrients can be increased in the body (Boland, 2013). SOD is one of the important antioxidant enzymes of reactive oxygen scavenging in the biological system. It can effectively prevent the damage caused by reactive oxygen species inside the body, prolong the preservation time of fermented substances and has significant curative effect on autoimmune diseases and cardiovascular and cerebrovascular diseases (Wang et al., 2018).

The enzyme activity of kiwifruit fresh fruit has been reported, but there are few studies on the enzyme activity of kiwifruit fermented, especially protease and SOD. As shown in Figure 4, with the increase of fermentation time, the activity of protease and SOD in each group showed a stable increase, and the activity of HKF group was higher than that of the other three groups. Both of protease and

**Figure 3.** Antioxidant activities of different fermentation of kiwifruit determined. */**: HKF is compared with NHKF; */**: CKF is compared with NCKF. Data are presented as mean ± SD (n = 3), with */**: p < .05; **/**: p < .01.
SOD concentration were significantly different between artificial fermentation and natural fermentation groups \((p < .05)\). In addition, HKF group protease activity reached 4.42 U/100 g FW and SOD activity reached 55.11 U/100 g FW at 21 days of fermentation, which was significantly higher than a previous report of fresh kiwifruit (Xu et al., 2019). In addition, the protease activity and SOD of HKF group was 1.28 and 2.22 times higher than that of CKF, and SOD had the most obvious antioxidant effect. In a word, fermentation can improve the content of protease and SOD of kiwifruit, and the content in HFK group was higher.

**Conclusion**

In this study, the two *Actinidia* genotypes cultivated in China were processed as raw materials to develop fermented products, and the relevant indicators were determined. Although the SSC and TP
in each group decreased significantly during the fermentation process, antioxidant and enzyme activities increased. Whole fruit fermentation of kiwifruit could maximize the value of kiwi nutrition and the Hongyang kiwi fermented products showed better biological activities than green kiwi fermented products. The SSC, TP, antioxidant activity and enzyme activity of HKF were higher than those of CKF products. ABTS·+ and SOD activities were more obvious, which were 2.22 times and 1.42 times of CKF group, respectively. The processed kiwifruit fermentation product is superior to the natural fermentation product in activities.

The results showed that the fermentation products of different varieties of kiwifruit were different, and Hongyang kiwi was more suitable for the development of fermentation products. Therefore, fermentation can stimulate the potential vitality of kiwifruit, providing a method for in-depth research and development of functional products.

Disclosure Statement
No potential conflict of interest was reported by the author(s).

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Patents
The work reported in this manuscript has obtained an authorized patent of the People’s Republic of China (ZL 201810114340.5).

References
Boland, M. 2013. Kiwifruit proteins and enzymes: Actinidin and other significant proteins. Adv. Food Nutr.Res. 68:59–80. doi: 10.1016/B978-0-12-394294-4.00004-3.
Choi, J.-M., -S.-S. Han, and H.-S. Kim. 2015. Industrial applications of enzyme biocatalysis: Current status and future aspects. Biotechnol Adv 33(7):1443–1454. doi: 10.1016/j.biotechadv.2015.02.014.
Di Cagno, R., R. Coda, D. Angelis, and M. Gobbetti. 2013. Exploitation of vegetables and fruits through lactic acid fermentation. Food Microbiol 33(1):1–10. doi: 10.1016/j.fm.2012.09.003.
Eš, I., A.M. Khaneghah, F.J. Barba, J.A. Saraiva, A.S. Sant’Ana, and S.M.B. Hashemi. 2018. Recent advancements in lactic acid production - a review. Food Res. Int. 107:763–770. doi: 10.1016/j.foodres.2018.01.001.
Giuggioli, N.R., C. Baudino, R. Briano, and C. Peano. 2019. Quality of packed baby kiwi cultivar ‘Hortgem Tahi (R)’ and ‘Hortgem Rua (R)’. Prog Nutr. 21(2):440–448. doi:10.23751/pn. v21i2.7042.
Hashemi, S.M.B., A.M. Khaneghah, F.J. Barba, Z. Nematu, S.S. Shokofti, and F. Alizadeh. 2017. Fermented sweet lemon juice (Citrus limetta) using lactobacillus plantarum LSS: Chemical composition, antioxidant and antibacterial activities. J. Funct Foods. 38:409–414. doi: 10.1016/j.jff.2017.09.040.
He, X.R., J.C. Fang, X.F. Chen, Z.F. Zhao, Y.S. Li, Y.B. Meng, and L.H. Huang. 2019. *Actinidia* chinensis planch.: A review of chemistry and pharmacology. Front. Pharmacol. 10:1236. doi: 10.3389/fphar.2019.01236.

Huang, Z.Y., J. Li, J.F. Zhang, Y.Y. Gao, and G.H. Hui. 2017. Physicochemical properties enhancement of Chinese kiwi fruit (*Actinidia chinensis* Planch.) via chitosan coating enriched with salicylic acid treatment. Food Measure 11 (1):184–191. doi: 10.1007/s11694-016-9385-1.

Hur, S.J., S.Y. Lee, Y.C. Kim, I. Choi, and G.B. Kim. 2014. Effect of fermentation on the antioxidant activity in plant-based foods. Food Chem. 160:346–356. doi: 10.1016/j.foodchem.2014.03.112.

Kaprasob, R., O. Kerdchoechuen, N. Laohakunjit, D. Sarkar, and K. Shetty. 2017. Fermentation-based biotransformation of bioactive phenolics and volatile compounds from cashew apple juice by select lactic acid bacteria. Process Biochem. 59:141–149. doi: 10.1016/j.procbio.2017.05.019.

Kim, A.N., H.J. Kim, J. Chun, H.J. Heo, W.L. Kerr, and S.G. Choi. 2019. Degradation kinetics of phenolic content and antioxidant activity of hardy kiwifruit (*Actinidia arguta*) puree at different storage temperatures. LWT. 89:535–541. doi: 10.1016/j.lwt.2017.11.036.

Lei, X.J., Z.Y. Wu, C.Y. Cui, J. Yang, and W.X. Zhang. 2016. Increasing protease activities and antioxidant properties of Koji for soy sauce brewing by adding a medicinal herb *Rhodiola rosea*. Food Eng 12(3):247–256. doi: 10.1515/jfpe-2015-0187.

Leonotowicz, H., M. Leonotowicz, P. Latocha, I. Jesion, Y.-S. Park, E. Katrich, D. Barasch, A. Nemirovski, and S. Gorinstein. 2016. Bioactivity and nutritional properties of hardy kiwi fruit *Actinidia delicosa* 'Hayward' and *Actinidia eriantha* 'Bidan.' Food Chem. 196:281–291. doi: 10.1016/j.foodchem.2015.08.127.

Li, X.C. 2012. Improved pyrogallol autooxidation method: A reliable and cheapsuperoxide-scavenging assay suitable for all antioxidants. J. Agric.food.Chem 60(25):6418–6424. doi: 10.1021jf204970r.

Li, W.W., G.S. Fan, Z.L. Fu, W.H. Wang, Y.Q. Xu, T.C. Teng, C.N. Zhang, R. Yang, B.G. Sun, and X.T. Li. 2020. Effects of fortification of Daqu with various yeasts on microbial community structure and flavor metabolism. Food Res. Int 129:108837. 2020 doi: 10.1016/j.foodres.2019.108837.

Liu, J., N. Arneborg, T.B. Toldam-Andersen, S.J. Zhang, M.A. Petersen, and W.L.P. Bredie. 2017. Impact of sequential co-culture fermentations on flavour characters of Solaris wines. Eur. Food Res. Technol 243(3):437–445. doi: 10.1007/s00217-016-2757-2.

Liu, D., J.N. Xu, Y.F. Cao, Y.M. Qi, K. Yang, X.Y. Wei, Y.H. Xu, and M.T. Fan. 2020. Effect of glutathione-enriched inactive dry yeast on color, phenolic compounds, and antioxidant activity of kiwi wine. J Food Process Preserv 44(3): e14347. doi: 10.1111/jfpp.14347.

Ma, T.T., T. LAN, Y.L. Ju, G. Cheng, Z.L. Que, T.H. Geng, Y.L. Fang, and X.Y. Sun. 2019. Comparison of the nutritional properties and biological activities of kiwifruit (*Actinidia*) and their different forms of products: Towards making kiwifruit more nutritious and functional. Food Funct 10(3):1317–1331. doi: 10.1039/C8FO02322K.

Markkinnen, N., O. Laaksonen, R. Nahku, R. Kuldjärv, and B. Yang. 2019. Impact of lactic acid fermentation on acids, sugars, and phenolic compounds in black chokeberry and sea buckthorn juices. Food Chem. 286:204–215. doi: 10.1016/j.foodchem.2019.01.189.

Ma, T.T., X.Y. Sun, J.M. Zhao, Y.L. You, Y.S. Lei, G.T. GAO, and J.C. Zhan. 2017. Nutrient compositions and antioxidant capacity of kiwifruit (*Actinidia*) and their relationship with flesh color and commercial value. Food Chem. 218:294–304. doi: 10.1016/j.foodchem.2016.09.081.

Nie, J., S.L. Yang, M.H. Mo, and Z.H. Hu. 2017. In vitro antioxidant activity of hot water extracts from 7 different sources of ganoderma lucidum. Medicinal Plant 8(4):62–65,71. doi: 10.19600/j.cnki.2152-3924.2017.04.014.

Park, Y.S., M.H. Im, J.-H. Choi, S.-H. Yim, H. Leontowicz, M. Leontowicz, M. Suhaj, and S. Gorinstein. 2013. The effects of ethylene treatment on the bioactivity of conventional and organic growing ‘Hayward’ kiwi fruit. Scientia Horticulacteae (164):589–595. doi: 10.1016/j.scienta.2013.10.016.

Re, R., N. Pellegrini, A. Proteggente, A. Pannala, M. Yang, and C. Rice-Evans. 1999. Antioxidant activity applying an improved ABTS radical cation decolorization assay. Free Radical Bio Med 26(9–10):1231–1237. doi: 10.1016/S0891-5849(98)00315-3.

Richardson, D.P., J. Ansell, and L.N. Drummond. 2018. The nutritional and health attributes of kiwifruit: A review. Eur JNutr 57(8):2659–2676. doi: 10.1007/s00394-018-1627-z.

Sanlier, N., B.B. Gokcen, and A.C. Sezgin. 2019. Health benefits of fermented foods. Crit Rev Food Sci 59(3):506–527. doi: 10.1080/10408398.2017.1383355.

Septembre-Malatterre, A., F. Remize, and P. Poucheret. 2018. Fruits and vegetables, as a source of nutritional compounds and phytochemicals: Changes in bioactive compounds during lactic fermentation. Food Res. Int. 104:8699. doi: 10.1016/j.foodres.2017.09.031.

Sun, X., X. Chen, L. Li, T. Ma, F. Zhao, W. Huang, and J. Zhan. 2015. “Effect of ultra-high-pressure treatment on the chemical properties, colour and sensory quality of young red wine.” *S Afr J Enol Vitic* 36 (3):393–401. 2015.

Su, X.Y., Z.Y. Wang, and J.R. Liu. 2009. In vitro and in vivo antioxidant activity of Pinus koraiensis seed extract containing phenolic compounds. Food Chem 117(4):681–686. doi: 10.1016/j.foodchem.2009.04.076.

Szutowska, J. 2020. Functional properties of lactic acid bacteria in fermented fruit and vegetable juices: A systematic literature review. Eur. Food Res. Technol 246(3):357–372. doi: 10.1007/s00217-019-03425-7.
Tamang, J.P., P.D. Cotter, A. Endo, S.N. Han, R. Kort, S.Q. Liu, B. Mayo, N. Westerik, and R. Hutkins. 2020. Fermented foods in a global age: East meets West. Compr Rev Food Sci Food Saf 19(1):184–217. doi: 10.1111/1541-4337.12520.

Tilahun, S., H.R. Choi, D.S. Park, Y.M. Lee, J.H. Choi, M.W. Baek, K. Hyok, S.M. Park, and C.S. Jeong. 2020. Ripening quality of kiwifruit cultivars is affected by harvest time. Sci. Hortic. 261:108936. doi: 10.1016/j.scienta.2019.108936.

Wang, D.Q., L.Q. Chen, F. Yang, H.Y. Wang, and L. Wang. 2019. Yeasts and their importance to the flavour of traditional Chinese liquor: A review. J. Inst. Brew 125(2):214–221. doi: 10.1002/jib.552.

Wang, S.N., Y. Qiu, and F. Zhu. 2021. Kiwifruit (Actinidia spp.): A review of chemical diversity and biological activities. Food Chem. 350:1328469. doi: 10.1016/j.foodchem.2020.128469.

Wang, Y., C.L. Zhao, J.Y. Li, Y.J. Liang, R.Q. Yang, J.Y. Liu, Z. Ma, and L. Wu. 2018. Evaluation of biochemical components and antioxidant capacity of different kiwifruit (Actinidia spp.) genotypes grown in China. BiotechnolBiote 32(3):558–565. doi: 10.1080/13102818.2018.1443400.

Wojdyło, A., P. Nowicka, J. Oszmiański, and T. Golis. 2017. Phytochemical compounds and biological effects of Actinidia fruits. J. Funct. Foods. 30:194–202. doi: 10.1016/j.jff.2017.01.018.

Wu, D.T., W. Liu, Q.H. Han, G. Du, H.Y. Li, Q. Yuan, Y. Fu, L. Zhao, Q. Zhang, S.Q. Li, et al. 2019. Physicochemical characteristics and antioxidant activities of non-starch polysaccharides from different kiwifruits. Int. J. Biol. Macromol. 136:891–900. doi: 10.1016/j.jbiomac.2019.06.142.

Xu, F.X., S.Y. Liu, S.Z. Dong, J. Xu, T. Liu, and S. Dong. 2019. Effectiveness of lysozyme coatings and 1-MCP treatments on storage and preservation of kiwifruit. Food Chem. 288:201–207. doi: 10.1016/j.foodchem.2019.03.024.