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Comparative Effects of Hibiscus Leaves and Potato Peel Extracts on Characteristics of Fermented Orange Juice

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HIGHLIGHTS

- The results showed no significant mean difference (p>0.05) between samples in acidity.
- FHL_{10} registered the highest values in total solid solution, vitamin C, antioxidants profile, and sensory evaluation.
- The extracts of hibiscus leaves and potato peel can improve acceptability and shelf life of fermented orange juice.

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Acronyms and abbreviations
CFU=Colony Forming Unit
DPPH=2,2-Diphenyl-1-Picrylhdrazyl
GAE=Gallic Acid Equivalents
LAB=Lactic Acid Bacteria
QE=Quercetin Equivalent
TFC=Total Flavonoids Content
TPC=Total Phenolic Content
TSS=Total Soluble Solid

ABSTRACT

Background: Fermented foods are gaining interest because of their ability to improve health, as well as their good taste, and the desire of many to eat them. This investigation aimed to enhance the chemical and physical properties, sensory evaluation, and shelf life of fermented orange juice by adding liquid hibiscus leave (*Hibiscus sabdariffa*) and potato peel (*Solanum tuberosum)* extracts.

Methods: The extracts of hibiscus leaves and potato peel were added to fermented orange juice, and the samples were divided into five parts. Two parts with different concentrations of hibiscus leave extracts (5%, FHL_5 and 10%, FHL_{10}), and the other two parts with different concentrations of potato peel extracts (5%, FPP_5 and 10%, FPP_{10}). The Fifth part was fermented orange juice without any additives (PC). Then, they were estimated for the acidity, total solid solution, viscosity, carbohydrates, vitamin C, antioxidants profile, color, total microbial count, and sensory evaluation during storage time at 4±2 °C. Statistical analysis was done by IBM SPSS version 25.0 software.

Results: The results showed no significant mean difference (p>0.05) between samples in acidity. FHL_{10} registered the highest values in total solid solution, vitamin C, antioxidants profile, and sensory evaluation, while FPP_{10} registered the highest values in viscosity and total microbial count. Also, FPP_{10} registered the highest values in overall acceptability (8.85±0.24, 8.78±0.26, 8.71±0.26, and 8.78±0.26 at zero, 7th, 14th, and 21st days of storage time, respectively) followed by FPP_5 with no significant mean difference values (p>0.05).

Conclusion: The extracts of hibiscus leaves and potato peel can improve acceptability and shelf life of fermented orange juice summarized in the enhancement vitamin content, antioxidants profile, color, and sensory properties.

Introduction

Citrus fruits, especially oranges, are among the most popular consumed worldwide. In the recent years, citrus fruits received considerable attention which has the potential curative benefits associated with high levels

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of flavonoids, antioxidant, anticancer, as well as anti-inflammatory properties (Benavente-García and Castillo, 2008). World production of oranges is estimated approximately 73,298,838 tons annually. An alternative to waste post-harvest is to process the fruit and produce industrial products such as juices, jams, wines, etc. The use of the fermentation of orange fruits as a substrate for producing high-quality value products has been accomplished; an example is wines obtained by the fermentation of fruit (González et al., 2010).

Lactic Acid Bacteria (LAB) have positive health-promoting effects, e.g. regulating the intestinal flora, decreasing cholesterol level in the blood, strengthening the immune system, and ameliorating oral diseases (Hashemi et al., 2017; Kun et al., 2008). The fermented food with LAB also can prolong its shelf life, enhance the nutritional and organoleptic qualities, improve the sensory properties, and remove undesirable compounds (Kaprasob et al., 2017). The traditional study of LAB fermentation focuses on dairy products, which are unsuitable for vegans, lactose, and casein intolerant individuals; and high cholesterol risk individuals (Wu et al., 2020). Thus, the request for the development of non-dairy LAB fermentation food products was pointedly increasing. Fruit juices have been proposed as an alternative vehicle for LAB fermentation due to the high contents of minerals, vitamins, dietary fiber, and antioxidant compounds (Costa et al., 2013; Wu et al., 2020).

El-Hadary et al. (2022) mentioned that pomace and peels (food manufactories by-products) are abundant sources of bioactive compounds. Generally, the by-products of food manufactories did not use, however transaction food manufactories process to environmentally friendly ways becoming a highly important issue. The processing of by-products can generate high food additives value products such as flavonoids (rutin and luteolin), polyphenols (mainly oleuropein and hydroxytyrosol), etc. use in food preparation and manufacturing that increased the shelf life and oxidative stability of stored food products (Canabarro et al., 2019).

The antioxidants are one of most important food additives which used to elongate the shelf life of food products and preserve the nutritional quality of lipid and modify the consequences of oxidative damage in the human body (Canabarro et al., 2019). Natural antioxidants are used instead of synthetic ones to inhibit lipid oxidation in foods to improve their quality and nutritional value. In recent years, several natural antioxidants were used in food preparation and manufacturing which have increased the shelf life and oxidative stability of stored food products (El-Hadary et al., 2022).

Hibiscus (*Hibiscus sabdariffa*) is an important medicinal plant widely distributed in many several areas around the world. Hibiscus characterizes by the presence of phytochemical compounds like flavonoids, phenolic acids, and polysaccharides (Vasudeva and Sharma, 2008). Preliminary phytochemical screening revealed the presence of polyphenols in the leaves extractof hibiscus; also, a recent study indicated that leaves extract of hibiscus had high antioxidant effects (Nade et al., 2010). In addition, potatoes (*Solanum tuberosum)* are peeled during processing. The potato peels are a good source of natural antioxidants. Polyphenols are considered as important groups of natural antioxidants, which are present in potatoes (El-Hadary et al., 2022).

The aims of the present investigation were to the enhancement physical, chemical, and microbiological properties, sensory evaluation, andshelf life of fermented orange juice by hibiscus leaves and potato peel extracts additives.

Materials and methods

Materials

Orange fruits (*Citrus xsinensis*) were obtained from a private farm from Ismailia governorate, Egypt**.** Hibiscus leaves were obtained from aprivate farm from Sharqia governorate, Egypt. Potato wastes (*S. tuberosum*) were obtained from farm frites factory.

Chemicals and reagents

Citric acid, sodium carbonate (Na_2CO_3), sodium hydroxide (NaOH), phenolphthalein, absolute ethanol alcohol, potassium iodide, sodium thiosulfate, starch, chloroform, acetic acid, and hydrochloric acid were purchased from El-Gomhoria chemical company, Zagazig, Egypt. Thiobarbituric Acid (TBA), β-carotene, linoleic acid, tween 20, folin-ciocalteu reagent, gallic acid, phosphatidyl-choline, potassium chloride, iron chloride, Trichloroacetic Acid (TCA), 2,2-Diphenyl-1-Picrylhdrazyl (DPPH), and Butylated Hydroxyl Anisole (BHA) were purchased from Sigma chemical company, Cairo, Egypt. *Lactobacillus plantarum* (EMCC 1027) and *L. bulgaricus* (EMCC 1102) were obtained from the Egyptian Microbial Culture Collection (EMCC) of Cairo MIRCEN, Faculty of Agriculture, Ain Shams University, Egypt.

Preparation of samples

Firstly, the different parts of potato factories' wastes (30 kg; water, starch, and peels) were separated. Then, the potato peels were transferred and washed well with

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tap water to get rid of the remnants of starch sticking out, and stacked on trays for a 30 min to get rid of excess water before drying. The hibiscus leaves were examined to eliminate the undesirable parts and stacked on trays. Both samples were dried in an oven-dryer at 37 °C for 48 h. The samples were flipping once every hour in the first 4 h. Then, the dried samples were ground to a fine powder, place in plastic bags, wrapped with aluminum foil, and stored at -20 °C until the next procedures (El-Hadary et al., 2022).

Extraction of the antioxidants extracts

The extraction of hibiscus leaves and potato peel extracts of dried samples was conducted using the difference in pressure in 70% concentrations of ethanoic alcohol (El-Hadary et al., 2022). One hundred g of dried weight of hibiscus leaves and potato peel were soaked in 1,000 ml of 70% concentrations of ethanoic alcohol in 2,000 ml conical flask for 6 h with decrease the pressure to 0.6 Pa every 30 min in the sample flask during extraction. The obtained extracts were filtered using paper (Whatman No. 1, England), concentrated using a rotary evaporator (EYELA, Japan) until disappearing the alcoholic odor. Then, they were stored at 4±2 °C until the next procedures (El-Hadary et al., 2022).

Preparation of orange juice and inoculum

The orange fruit was washed with tap water, the pulp was chopped, and the seedswere removed. Then, the orange pulp was crushed using a food-grade juicer and filtered through 80 mesh gauze. Orange juice was divided into five parts. The first part was orange juice with 5% of Hibiscus Leaves extracts (HL_5), the second part was orange juice with 10% of Hibiscus Leaves extracts (HL_{10}), the third part was orange juice with 5% of Potato Peel extracts (PP_5), the fourth part was orange juice with 10% of Potato Peel extracts (PP_{10}), while the Fifth part was orange juice without any additives (PC). Then, the samples were pasteurized at 80 °C for 15 min and cooled to room temperature (25 °C) (Burca-Busaga et al., 2022).

The used cultures were grown at 37 °C separately for 24 h in de Man Rogosa Sharpe (MRS) broth (Difco Laboratories, Detroit, MI, USA) in order to attain approximately 106 Colony-Forming Units (CFU)/ml as inoculating before inoculation into orange juice as 0.5% (V/V).

Enumeration of the cells was performed by plating serial dilutions of bacterial suspensions on MRS agar plates, and incubating at 37 ºC, and counting the colonies after 48 h. The inoculation by *L. plantarum* and *L. bulgaricus* was done in the range of CFU/ml, and then incubated at 37 ºC for 24 h to make sure the fermentation operation (Mousavi et al., 2011). After 24 h, the analysis was estimated at zero time. Then, the samples were storaged at 4±2 ºC for 21st days and analyzed every 7 days.

Determination carbohydrates

Total crude carbohydrates, reduced sugar, and non-reduced sugar of various samples were measured per the methods recommended in AOAC (2019).

Determination of pH

The pH of all samples was measured with a glass electrode of a digital pH meter (Model Mettler Toledo, Switzerland) (AOAC, 2019).

Determination of titratable acidity

The acidity of samples was evaluated by the overall titration method supported the carboxylic acid percentage (AOAC, 2019). A few drops of phenolphthalein were added to 20 ml of homogenized samples in a titration flask. Then, titration with 0.1 M NaOH until a faint pink color persists for 30 s. The concentration of citric acid calculated using theofficial equation depended on 1 ml of 0.1 M NaOH corresponding to 0.064 mg of citric acid.

Determination of Total Soluble Solids (TSSs)

TSSs and also the index of refraction were assayed using the refractometric method, with an Abbe refractometer and corrected to the equivalent reading at 20 °C (AOAC, 2019).

Determination of viscosity

The viscosity of every sample was resoluted at temperature by employing a Brookfield digital viscometer (NDJ-85, Niryn Intelligent Company limited, Shanghai). An acceptable spindle (spindle 2) and rotational speed (60 rpm) were selected for this study (Sun et al., 2006).

Determination of color

Orange juice color was measured using the Hunter-Lab (Hunter Lab Color Flex EZ, USA). Color parameter (L*) indicated the degree of lightness to darkness, (a*) indicated the degree of redness to greenness, and (b*) indicated the degree of yellowness to blueness (Zaki, 2022).

Determination of Total Phenolic Contents (TPC)

The content of total phenol concentration of various samples was measured by a UV spectrophotometer (Jenway-UV–VISSpectrophotometer, UK), supported a

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colorimetric oxidation/reduction reaction, that described by Škerget et al. (2005). The reagent of oxidizing was Folin–Ciocalteu reagent consistent with AOAC (2019). Five tenths ml of diluted extract (10 mg in 10 ml solvent), 2.5 ml of Folin–Ciocalteu reagent (diluted 10 times with distilled water), and a pair of ml of Na_2CO_3 (75 g/L) were added. The mixture was incubated for five min at 50 ˚C, and then cooled. For an effect sample, 0.5 ml of water was used. The absorbance was measured at 760 nm. TPC expressed as acid equivalent (Gallic Acid Equivalents (GAE)/g of dried extract) was calculated using the subsequent equation supported the calibration curve (Figure 1) by use the different concentrations of gallic acid (0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7 mg GAE/ml):

y=0.2269x+0.4847

R^2=0.992

Where y is that the absorbance; x is that the concentration (mg GAE/g of dried extract); R^2 is correlation coefficient.

Determination of Total Flavonoids Contents (TFCs)

The concentration of TFCs of various samples was measured according Ordoñez et al. (2006) with some modification description by El-Hadary et al. (2022). One point five ml of $AlCl_3$ ethanolic solution (20 g/L) was added to 0.5 ml of each extract of samples (10 mg in 10 ml solvent), separately and incubated for 1 h at room temperature. The absorbance was measured at 420 nm at room temperature and therefore the yellow color indicated the presence of flavonoids. TFC expressed as Quercetin equivalent (mg QE/g of dried extract) was calculated using the subsequent equation supported the calibration curve (Figure 2) by use the different concentrations of quercetin (0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7 mg QE/ml):

y=0.3531x+0.8191

R^2=0.992

Where x is that the absorbance; y is that the concentration (mg QE/g of dried extract); R^2 is correlation coefficient.

DPPH atom scavenging assay

The decolorization of deep purple color of methanolic DPPH˙ solution by various samples was measured according to Gülçin et al. (2004). One tenth ml of every extract (10 mg in 10 ml methanol solvent) was added to 3 ml of 0.1 mM DPPH˙ dissolved within the methanol solvent to every extract, separately, and measured for 2 h every 30 min at room temperature. The control of the assay was prepared consistent with usage to negative control from DPPH˙ solution and only solvent without extracts, and therefore the positive control by exchange the extracts by BHA synthetic antioxidants. The absorbance resolves against a negative control at 517 nm for each period, separately. Percentage of antioxidant activity of DPPH˙ radical was calculated using the subsequent equation:

$$\text{Inhibition (\%)} = \left(\frac{A_c - A_t}{A_c}\right) \times 100$$

Where, A_c is the absorbance of the negative control; A_t is the absorbance of the sample and/or positive control. IC_{50} is the antioxidant concentration that inhibits the DPPH˙ reaction by 50% under experimental conditions.

Determination of ascorbic acid

Vitamin C (ascorbic acid) content resolves using 2,6-dichlorophenol indophenol reagent (Fluka, Deisehofen, Germany) in step with the strategy described by AOAC (2019). One ml of sample was added to 1 ml of 50 mM solution of oxalic acid (1:1, v/v), mix thoroughly, and leave at room temperature for 30 min. Centrifugation of the tube at 4,000 rpm for 10 min, then the whole of the separated supernatant was collected with a pipette. The standard sample was prepared using 1 ml of the standard solution instead of the analyzed liquid without centrifugation. The absorbance measurements of the test sample (Ax) and standard sample (As) were determined at 700 nm against the mixture of 50 mM solution of oxalic acid (1:1, v/v) as a reference sample. The concentration of vitamin C (Cx: µM) in the liquid of different samples was calculated using the formula:

$$Cx = \frac{Ax}{As} \times Cs$$

Where, Cs is the concentration of vitamin C in standard solution.

Microbiological analysis

Viable cell counts were determined by serial dilutions and standard plate method after incubation. Dilutions of 10^{-7} and 10^{-8} CFU/ml were prepared of the fermented samples and plated in double plates. Then, sterilized MRS agar (Merck, Germany) medium was poured on them (standard plate count method) (Mousavi et al., 2011). The plates were incubated at 30 °C for 48 h. Then plates containing 30-300 colonies were counted and recorded as CFU per ml of solution (Vinderola et al., 2000). Additionally, the viability of lactic acid cultures was resoluted during the cold storage period using the mentioned method and expressed as CFU/ml (AOAC, 2019).

Sensory evaluation

Sensory evaluation was done per Min et al. (2003). Ten panelists were selected (Staff of Food Science

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Department, Faculty of Agriculture, Zagazig University, Egypt) without care old or sex. The panelists were asked to point their preference on a 9-point Hedonic scale with a degree of liking: 1=dislike extremely, 2=dislike greatly, 3=dislike moderately, 4=dislike slightly, 5=neither like nor dislike, 6=like slightly, 7=like moderately, 8=like a great deal, and 9=like extremely. In each session, five different samples got to rate the color, test, flavour, and overall acceptability of the samples.

Statistical analysis

The tests were exhausted triplicate in line with Steel et al. (1997), and therefore the data were analyzed using the means, variance by Microsoft Office Excel(2016), paired sample t-test, and one-way ANOVA variance analysis by IBM SPSS version 25.0 software (SPSS Inc., Chicago, IL, USA) at the extent of probability of (p<0.05).

Results

Acidity

The acidity of fermented orange juices were shown in Table 1. The results showed no significance means differences (p>0.05) between samples, and no significance means differences (p>0.05) between the values to the same sample during the time of storage. All samples showed low increases in acidity by progress in storage time. The highest value of acidity was 10% of Fermented Hibiscus Leave extracts (FHL_{10}), followed by other samples at 21st days of storage time. While, the lowest value of acidity was 10% of Fermented Potato Peels extracts (FPP_{10}) at zero time of storage.

Effect on TSS and viscosity

The results of TSS assay showed a significant means difference (p<0.05) between almost samples. The highest value of TSS was FHL_{10} at 21st days of storage time with a significant mean difference (p<0.05) between other samples with no significant mean difference (p>0.05) between FPP_5 and FPP_{10}, and the highest value was FHL_{10} after both 14th and 21st days of storage time (22.3±0.2 and 22.6±0.1, respectively) followed by FPP_5 after both 14th and 21st days of storage time (21.3±0.3 and 22.1±0.1, respectively). While, the lowest values were all samples at zero time of storage with a significant means difference (p<0.05) between PC and other samples (16.36±0.1); and no significant means difference (p>0.05) between FHL_5 and FPP_5 (15.82±0.12 and 15.85±0.1, respectively); and no significant means difference (p>0.05) between FHL_{10} and FPP_{10} (15.35±0.2 and 15.4±0.1, respectively). The results also showed the positive effect of the additives hibiscus leaves and potato peel extracts in TSS values of fermented orange juices during the time of storage.

All the samples registered the lowest viscosity values at zero time of storage with no significant means difference (p>0.05) between samples. The results also showed the increases in viscosity values by the progress in storage time with clear improvement in values of samples which have hibiscus leaves and potato peel extracts. All samples registered the highest value of viscosity at 21st days of storage time, and the highest value was FPP_{10} followed by FHL_{10} with no significant means difference (p>0.05) between both of them (14.5±0.3 and 14.3±0.2, respectively), while the lowest value was PC at zero time of storage (10.57±0.57) with no significant means difference (p>0.05) between PC and other samples.

Effect on vitamin C

The impact on the contents of vitamin C during the time of storage was measured and the results are shown in Table 2. The results showed little decrease in values of vitamin C by the progress of storage time to all the samples. The data at 21st registered the lowest value to all the samples and PC was the lowest (51.81±0.21 mg/g of wet weight) with significant mean difference (p<0.05) just with FHL_{10} (52.87±0.07 mg/g of wet weight). The results also showed a clear effect hibiscus leaves extracts additives during all the time of storage which showed significant mean difference (p<0.05) between FHL_{10} and all other samples during storage time.

Effect on carbohydrates

Data in Table 3 show the effect on reducing sugar, non-reducing sugar, and total carbohydrates; respectively. The results showed a decrease in reducing sugar, non-reducing sugar, and total carbohydrates values by progress in time of storage. The results also showed no significant means difference (p>0.05) between all the samples at all the time of storage, and no significance in means differences (p>0.05) between the values to the same sample during the time of storage to reducing sugar, non-reducing sugar, and total carbohydrates. The data at 21st days of storage time registered the lowest values of both reducing sugar, non-reducing sugar, and total carbohydrates to all the samples, while data at zero time was the highest. The reducing sugar represented a high percentage of total carbohydrates, which give 61.68% at the highest value and 60.91% at the lowest value.

Effect on antioxidants activities

The antioxidant activities of different fermented orange

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juices were measured by different methods and the results show in the Table 4. TPCs, TFCs, and DPPH˙scavenging radical activity (IC_{50}) were estimated. The results showed significance in means differences (p<0.05) between samples, and significance in means differences (p<0.05) between the values to the same sample during the time of storage. The results also showed a clear positive effectof hibiscus leaves and potato peel extracts additives by the decreases in IC_{50} value during storage time to all samples, however, the decreases in TPC and TFC values. The highest values of antioxidants activities wereat zero time of storage and the highest values were FHL_{10} to both TPCs and TFCs (448.15±1.15 mg GAE/g and 115.2±0.2 mg QE/g, respectively), and PC in IC_{50} estimated (43.56±0.56 µg/g of wet weight).

Effect on color

The impact of ethanolic hibiscus leaves and potato peel extracts on the color ofdifferent fermented orange juices was measured. Table 5 showed values of lightness (L*), redness (a*), and yellowness (b*), respectively. The results showed decreases in lightness (L*), redness (a*), and yellowness (b*) by the progress in time of storage. However, there was the little significant mean differences (p<0.05) between samples in lightness (L*) values during storage time, while there was no significant mean differences (p>0.05) between samples at 7th days of storage time. The results registered a clear effect to additives hibiscus leaves extracts on redness (a*) values which FHL_{10} gave the highest values of redness (a*) during storage time (62.62±0.12, 61.95±0.45, 61.1±0.1, and 60.44±0.44 at zero, 7th, 14th, and 21st days of storage time, respectively), and positive effect to additives potato peel extracts on yellowness (b*) values which FPP_{10} gave the highest values of yellowness (b*) during storage time (82.87±0.37, 80.73±0.23, 79.52±0.52, and 78.37±0.37 at zero, 7th, 14th, and 21st days of storage time, respectively).

Effect on the total microbial count

The totalmicrobial count of different fermentedorange juices was estimated and the results are shown in Table 6. The results showed a few significant mean differences (p<0.05) between samples during the time of storagewith no significant mean differences (p>0.05) between the values to the same sample during storage time, however, the increases in total microbial count values. The results also showed the positive effect to additives hibiscus leaves and potato peel extracts, while PC gave the lowest values of totalmicrobial count with clear significant mean differences (p<0.05) between samples during the time of storage. All the samples showed no significant mean differences (p> 0.05) during storage time accepted PC which gave significant mean differences (p<0.05) between the values at 14th and 21st days of storage time.

Effect on sensory evaluation

Sensory evaluation of different fermented orange juices was estimated and the results are shown in Table 7. The results showed the effect on color, tastes, flavour, and overall acceptability. Potato peel extracts were a positive effect on all sensory evaluations, while additives hibiscus leaves extracts had a negative effect on color evaluation at 10% during all the time of storage. In general, the data showed more acceptability to the FPP_{10}>FPP_5>FHL_{10}>FHL_5>PC to all sensory evaluations during all the time ofstorage, and all the degree was ≥7. Almost all panelists were attributing positive effect of potato peel extracts additives to enhance the appearance and flavour, in addition to the decreases in sensory evaluations to PC was attributing to the little bitter taste to the control sample in the last time of storage.

Discussion

The increases in acidity by adding hibiscus leaves and potato peels extracts and also the progress in time of storage may be because of the positive of these extracts on protect citric acid from metabolized by bacterial after fermentation starts, which also explains the decreases of total carbohydrates (both reduce and non-reduce sugar). The appropriate explanation for this phenomenon is the availability of carbohydrates in high concentrations in orange juice. Mousavi et al. (2011) had different results when fermenting a pomegranate juice by probiotic bacteria due to the considerable amounts of organic acid i.e., citric acid in pomegranate juice that was used.

The effect on viscosity, TSS, and a lightness of juice color may be due to the volume of bacterial growth. The spoilage and bacterial growth of food bring about physical changes such as an increase in the viscosity, gelation, sedimentation, and/or color change of the food. First of place, the increases in viscosity by the progress in time of storage and by adding the extracts due to the enhancement of the bacterial growth that has acted to generate the products which have a viscous effect. Also, the increase in TSS by adding the hibiscus leaves and potato peels extracts compared with the control sample attributed to the increases in metabolized resulting from the high volume of bacterial growth. In addition, Quan et al. (2022) attributed the increase in TSS to the ability of bacteria on metabolize organic compounds in fermented orange juices.

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Table 1: Acid value of different fermented orange juice samples treated with hibiscus leaves and potato peel extracts

Samples	mg of citric acid/g of wet weight/days-time of storage			
	0	7	14	21
PC	0.93±0.03 [a]	0.96±0.02 [a]	1.05±0.1 [a]	1.2±0.1 [a]
FHL_5	0.92±0.02 [a]	0.98±0.02 [a]	1.05±0.05 [a]	1.2±0.2 [a]
FHL_{10}	0.92±0.01 [a]	1±0.05 [a]	1.13±0.13 [a]	1.26±0.06 [a]
FPP_5	0.93±0.03 [a]	0.97±0.02 [a]	1.05±0.05 [a]	1.2±0.2 [a]
FPP_{10}	0.91±0.01 [a]	0.98±0.03 [a]	1.07±0.07 [a]	1.2±0.15 [a]

Values mean±SD; n=3. Different letters in the same column indicate significant differences (p<0.05).
PC: positive control
FHL_5: 5% of fermented hibiscus leaves extracts
FHL_{10}: 10% of fermented hibiscus leaves extracts
FPP_5: 5% of fermented potato peels extracts
FPP_{10}: 10% of fermented potato peels extracts.

Table 2: The contents of vitamin C of different fermented orange juice samples treated with hibiscus leaves and potato peel extracts

Samples	mg/100 g of wet weight/days-time of storage			
	0	7	14	21
PC	52.86±0.36 [c]	52.2±0.2 [c]	52.03±0.3 [b]	51.81±0.21 [b]
FHL_5	53.22±0.12 [ab]	52.91±0.05 [b]	52.46±0.2 [b]	52.2±0.2 [b]
FHL_{10}	53.73±0.23 [a]	53.52±0.5 [a]	53.08±0.08 [a]	52.87±0.07 [a]
FPP_5	53±0.5 [b]	52.8±0.3 [bc]	52.43±0.43 [b]	52.2±0.2 [b]
FPP_{10}	52.61±0.11 [d]	52.42±0.42 [c]	52±0.5 [b]	51.85±0.35 [b]

Values mean±SD; n=3. Different letters in the same column indicate significant differences (p<0.05).
PC: positive control
FHL_5: 5% of fermented hibiscus leaves extracts
FHL_{10}: 10% of fermented hibiscus leaves extracts
FPP_5: 5% of fermented potato peels extracts
FPP_{10}: 10% of fermented potato peels extracts.

Table 3: The contents of carbohydrates of different fermented orange juice samples treated with hibiscus leaves and potato peel extracts

	Samples	g carbohydrates/100 g of wet weight/days-time of storage			
		0	7	14	21
Reducing sugars	PC	7.76±0.66 [a]	7.75±0.25 [a]	7.63±0.13 [a]	7.6±0.3 [a]
	FHL_5	7.72±0.22 [a]	7.7±0.2 [a]	7.61±0.11 [a]	7.52±0.42 [b]
	FHL_{10}	7.63±0.13 [b]	7.63±0.2 [b]	7.5±0.4 [b]	7.43±0.1 [c]
	FPP_5	7.7±0.2 [a]	7.71±0.21 [a]	7.62±0.32 [a]	7.52±0.22 [b]
	FPP_{10}	7.56±0.25 [c]	7.55±0.55 [c]	7.4±0.3 [c]	7.31±0.2 [d]
Non-reducing sugars	PC	4.82±0.16 [b]	4.71±0.21 [ab]	4.69±0.19 [b]	4.6±0.1 [b]
	FHL_5	4.78±0.08 [b]	4.71±0.51 [ab]	4.69±0.09 [b]	4.66±0.24 [a]
	FHL_{10}	4.83±0.13 [b]	4.69±0.02 [b]	4.7±0.2 [b]	4.62±0.05 [b]
	FPP_5	4.82±0.62 [b]	4.75±0.67 [a]	4.73±0.68 [ab]	4.68±0.42 [a]
	FPP_{10}	4.88±0.65 [a]	4.75±0.85 [a]	4.76±0.46 [a]	4.69±0.3 [a]
Total carbohydrates	PC	12.58±0.5 [a]	12.46±0.46 [a]	12.32±0.32 [a]	12.2±0.2 [a]
	FHL_5	12.5±0.3 [b]	12.41±0.31 [a]	12.3±0.2 [a]	12.18±0.18 [a]
	FHL_{10}	12.46±0.26 [c]	12.32±0.22 [b]	12.2±0.2 [b]	12.05±0.15 [b]
	FPP_5	12.52±0.42 [b]	12.46±0.46 [a]	12.35±0.35 [a]	12.2±0.2 [a]
	FPP_{10}	12.44±0.4 [c]	12.3±0.3 [b]	12.16±0.16 [b]	12±0.5 [b]

Values mean±SD; n=3. Different letters in the same column indicate significant differences (p<0.05).
PC: positive control
FHL_5: 5% of fermented hibiscus leaves extracts
FHL_{10}: 10% of fermented hibiscus leaves extracts
FPP_5: 5% of fermented potato peels extracts
FPP_{10}: 10% of fermented potato peels extracts.

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Table 4: The antioxidants activities–Total Phenolic Contents (TPCs; concentration mg GAE/g of wet weight) and Total Flavonoids Contents (TFCs; concentration mg QE/g of wet weight) of different fermented orange juice samples treated with hibiscus leaves and potato peel extracts

	Samples	Days/time of storage			
		0	7	14	21
TPC	PC	431.25±1.25 ^{e}	430.24±1.24 ^{e}	428.45±2.45 ^{e}	428.1±1.1 ^{e}
	FHL_5	442.73±1.23 ^{b}	440.42±0.42 ^{b}	439.52±0.52 ^{b}	437.24±2.24 ^{b}
	FHL_{10}	448.15±1.15 ^{a}	446.45±0.45 ^{a}	445.05±1.05 ^{a}	443.12±0.12 ^{a}
	FPP_5	435.46±0.46 ^{d}	433.52±0.52 ^{d}	432.04±1.04 ^{d}	430.43±0.43 ^{d}
	FPP_{10}	438.73±0.73 ^{c}	437.19±1.19 ^{c}	435.53±0.53 ^{c}	433.16±0.16 ^{c}
TFC	PC	111.82±0.82 ^{c}	109.13±1.13 ^{c}	106.25±0.25 ^{c}	101.46±1 ^{c}
	FHL_5	113.45±0.45 ^{b}	112.05±1.05 ^{b}	110.59±0.59 ^{b}	108.25±0.25 ^{b}
	FHL_{10}	115.2±0.2 ^{a}	114.57±0.57 ^{a}	112.73±1.23 ^{a}	110.81±0.81 ^{a}
	FPP_5	110.12±1.12 ^{d}	108.94±0.94 ^{d}	105.81±0.81 ^{d}	99.84±0.84 ^{d}
	FPP_{10}	108.73±0.73 ^{e}	106.44±0.44 ^{e}	104.82±0.32 ^{e}	98.43±0.43 ^{e}

Values mean±SD; n=3. Different letters in the same column indicate significant differences (p<0.05).
PC: positive control
FHL_5: 5% of fermented hibiscus leaves extracts
FHL_{10}: 10% of fermented hibiscus leaves extracts
FPP_5: 5% of fermented potato peels extracts
FPP_{10}: 10% of fermented potato peels extracts.

Table 5: Color of different fermented orange juice samples treated with hibiscus leaves and potato peel extracts

	Samples	Days/time of storage			
		0	7	14	21
Lightness (L*)	PC	42.64±0.14 ^{a}	40.4±0.1 ^{a}	39.55±0.15 ^{a}	39±0.5 ^{a}
	FHL_5	42.1±0.1 ^{c}	40.2±0.1 ^{c}	39±0.5 ^{b}	38.32±0.32 ^{c}
	FHL_{10}	42.1±0.1 ^{c}	40.13±0.13 ^{e}	38.73±0.23 ^{c}	38±0.5 ^{d}
	FPP_5	42.26±0.26 ^{b}	40.26±0.26 ^{b}	39.6±0.3 ^{a}	39.01±0.5 ^{a}
	FPP_{10}	42.3±0.3 ^{b}	40.2±0.2 ^{c}	39.05±0.5 ^{b}	38.62±0.12 ^{b}
Redness (a*)	PC	52.43±0.43 ^{c}	52.21±0.21 ^{c}	51.62±0.12 ^{c}	51.13±0.13 ^{c}
	FHL_5	57.4±0.1 ^{b}	56.82±0.12 ^{b}	56.04±0.5 ^{b}	55.3±0.2 ^{b}
	FHL_{10}	62.62±0.12 ^{a}	61.95±0.45 ^{a}	61.1±0.1 ^{a}	60.44±0.44 ^{a}
	FPP_5	50.93±0.43 ^{e}	50.31±0.31 ^{d}	49.85±0.25 ^{d}	49.05±0.5 ^{d}
	FPP_{10}	51.02±0.52 ^{d}	50.1±0.1 ^{e}	49.67±0.17 ^{e}	48.72±0.22 ^{e}
Yellowness (b*)	PC	79.77±0.27 ^{c}	79.21±0.21 ^{c}	78.65±0.15 ^{c}	77.92±0.42 ^{c}
	FHL_5	77.01±0.51 ^{d}	76.3±0.2 ^{d}	75.62±0.12 ^{d}	74.73±0.23 ^{d}
	FHL_{10}	73.82±0.12 ^{e}	73.03±0.5 ^{e}	72.01±0.5 ^{e}	70.69±0.1 ^{e}
	FPP_5	80.22±0.22 ^{b}	79.99±0.49 ^{b}	78.75±0.25 ^{b}	78.09±0.5 ^{b}
	FPP_{10}	82.87±0.37 ^{a}	80.73±0.23 ^{a}	79.52±0.52 ^{a}	78.37±0.37 ^{a}

Values mean±SD; n=3. Different letters in the same column indicate significant differences (p<0.05).
PC: positive control
FHL_5: 5% of fermented hibiscus leaves extracts
FHL_{10}: 10% of fermented hibiscus leaves extracts
FPP_5: 5% of fermented potato peels extracts
FPP_{10}: 10% of fermented potato peels extracts.

Table 6: Total microbial counts of different fermented orange juice samples treated with hibiscus leaves and potato peel extracts

Samples	CFU/g×10^{-7}/Days-time of storage			
	0	7	14	21
PC	7.3±0.3 ^{c}	7.5±0.5 ^{c}	7.6±0.3 ^{c}	6.43±0.4 ^{d}
FHL_5	8.1±0.1 ^{b}	8.39±0.3 ^{b}	8.3±0.3 ^{b}	8.26±0.2 ^{c}
FHL_{10}	8.4±0.4 ^{ab}	8.62±0.6 ^{ab}	8.83±0.53 ^{a}	8.7±0.5 ^{b}
FPP_5	8.53±0.5 ^{a}	8.91±0.5 ^{a}	8.86±0.56 ^{a}	8.73±0.53 ^{b}
FPP_{10}	8.62±0.6 ^{a}	9.1±0.1 ^{a}	9.3±0.3 ^{a}	9.2±0.2 ^{a}

Values mean±SD; n=3. Different letters in the same column indicate significant differences (p<0.05).
PC: positive control
FHL_5: 5% of fermented hibiscus leaves extracts
FHL_{10}: 10% of fermented hibiscus leaves extracts
FPP_5: 5% of fermented potato peels extracts
FPP_{10}: 10% of fermented potato peels extracts.

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Table 7: Sensory evaluation of different fermented orange juice samples treated with hibiscus leaves and potato peel extracts

	Samples	Days/time of storage			
		0	7	14	21
Color	PC	8.5±0.53 ^{c}	7.93±0.85 ^{d}	8±0.5 ^{c}	7.85±0.95 ^{c}
	FHL_5	8.14±0.83 ^{d}	8.14±0.55 ^{c}	8.07±0.77 ^{b}	7.71±1.02 ^{d}
	FHL_{10}	7.57±0.53 ^{b}	7.64±0.76 ^{e}	7.5±0.55 ^{d}	7.35±1.52 ^{e}
	FPP_5	8.5±0.95 ^{c}	8.5±0.76 ^{b}	8.43±0.4 ^{a}	8.43±1.64 ^{b}
	FPP_{10}	8.64±0.75 ^{a}	8.71±0.55 ^{a}	8.43±0.43 ^{a}	8.57±2.03 ^{a}
Taste	PC	8.07±1.07 ^{d}	7.78±0.78 ^{e}	7.43±0.43 ^{d}	7.21±1.53 ^{d}
	FHL_5	8.28±0.58 ^{b}	8.35±0.55 ^{c}	7.85±0.85 ^{c}	7.64±1.64 ^{d}
	FHL_{10}	8.14±0.44 ^{c}	8.07±1.07 ^{d}	7.97±0.95 ^{b}	7.78±1.64 ^{c}
	FPP_5	8.64±0.65 ^{a}	8.5±0.55 ^{b}	8.35±0.35 ^{a}	8.28±0.52 ^{b}
	FPP_{10}	8.64±0.64 ^{a}	8.71±0.71 ^{a}	8.35±1.05 ^{a}	8.5±1.31 ^{a}
Overall acceptability	PC	7.85±0.89 ^{d}	7.85±1.13 ^{d}	7.43±0.95 ^{e}	7.14±2.3 ^{e}
	FHL_5	8.35±0.95 ^{b}	8.07±1.24 ^{c}	7.85±0.67 ^{d}	7.57±1.5 ^{d}
	FHL_{10}	8.21±1.12 ^{c}	8±0.69 ^{c}	8.14±0.67 ^{c}	8.43±0.95 ^{c}
	FPP_5	8.35±1.06 ^{b}	8.42±0.87 ^{b}	8.5±0.55 ^{b}	8.64±1.02 ^{b}
	FPP_{10}	8.71±0.83 ^{a}	8.71±0.64 ^{a}	8.85±0.92 ^{a}	8.78±1.02 ^{a}
	PC	7.71±0.26 ^{e}	7.57±0.44 ^{e}	7.28±0.26 ^{e}	7±0.28 ^{d}
	FHL_5	8.43±0.88 ^{c}	8.14±0.55 ^{d}	7.71±0.7 ^{d}	7.93±0.89 ^{c}
	FHL_{10}	8.14±1.2 ^{d}	8.21±0.59 ^{c}	8±0.25 ^{c}	7.93±0.1.02 ^{c}
	FPP_5	8.78±0.26 ^{b}	8.78±0.26 ^{b}	8.57±0.34 ^{b}	8.5±0.4 ^{b}
	FPP_{10}	8.85±0.24 ^{a}	8.78±0.26 ^{a}	8.71±0.26 ^{a}	8.78±0.26 ^{a}

Values mean±SD; n=3. Different letters in the same column indicate significant differences (p<0.05).
PC: positive control
FHL_5: 5% of fermented hibiscus leaves extracts
FHL_{10}: 10% of fermented hibiscus leaves extracts
FPP_5: 5% of fermented potato peels extracts
FPP_{10}: 10% of fermented potato peels extracts.

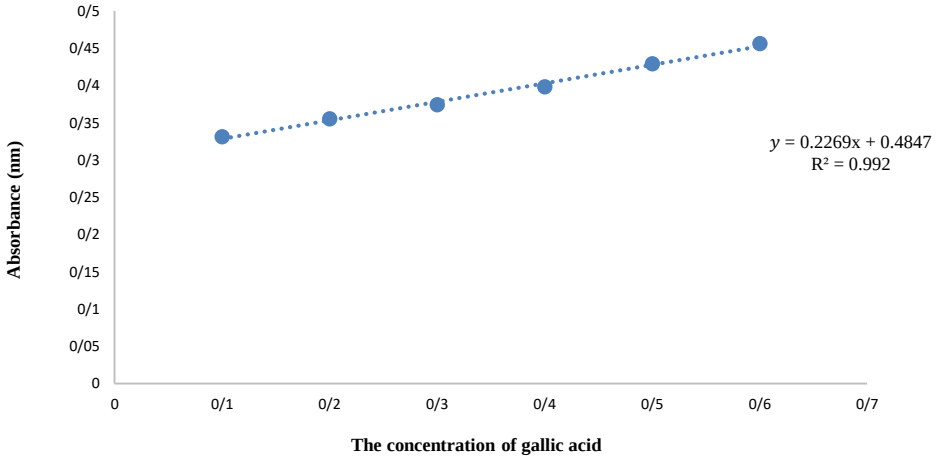

Figure 1: The stander carve of gallic acid

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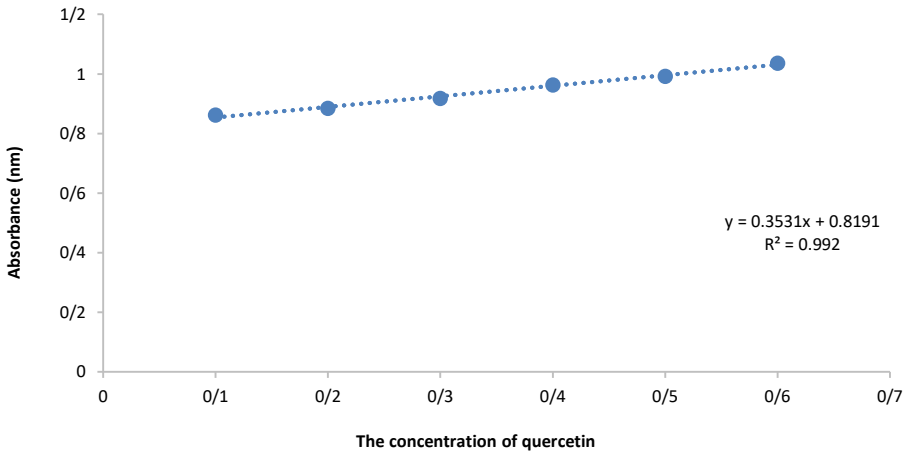

Figure 2: The stander carve of quercetin

The different concentrations of vitamin C between the control sample and the samples which had hibiscus leaves and potato peels extracts may be attributed to the concentrations of vitamin C in these extracts. In addition, the decrease in vitamin C values during storage time may be attributed to the consumption in the nurture of the microorganisms. Also, the increase in vitamin C concentration of samples that had hibiscus leaves and potato peels extracts is due to the protective effect of these extracts on vitamin C consumption by oxidative process and/or bacterial metabolized. Quan et al. (2022) attributed the increase in vitamin C concentration in samples of fermented orange juice to the ability of probiotic bacteria to generation vitamin C.

The results of antioxidants activity by different methods shown the hibiscus leaves and potato peels extracts exhibited high potential antioxidant. In addition, fermentation has a positive affect that shown from the increase in DPPH· scavenging radical activities (IC_{50}) during storage time. The data was similar to a previous study on the effects of *L. plantarum* fermentation on phenolic characteristics and various polyphenol compounds, even thoughdifferent raw materials (Li et al., 2021). The increases in DPPH· scavenging radical activities (IC_{50}) during storage time, however the decreases in TPC may be because of production enzymes or some other bioactive compounds which had an antioxidants effect or by the decreases in TFC which had a negative effect on antioxidants activities. Orange juice in different fermentation stages had different antioxidant activities, but overall, theantioxidant activity continued to increase.

The turbidity of juice during the progress in time of storage, and the difference of color by the different additives of extracts may be attributed to the effect of these extracts on bacterial growth. The decreases in lightness (L*) values by the progress in time of storage may be because of the effect of bacterial cells, while the increases in redness (a*) values by additives hibiscus leave extracts, and yellowness (b*) values by additives potato peel extracts because the red color to hibiscus leaves extracts and yellow color to potato peel extracts. The data was similar to a previous study on the effects of *L. plantarum* fermentation on color characteristics which found a positive effect on turbidity by adding *L. plantarum* to mulberry juice, also the fermentation effect on both of redness and yellowness (Kwaw et al., 2018).

The little increase in the total microbial count during storage time indicated the positive effect of hibiscus leaves and potato peel extracts additives due to the contents of these extracts from important compounds use in microbial metabolized. Also, the protective effect of these extracts gave more validity to the products during the time of storage and more quality not only to microbial growth but also protected the important compounds which had a positive effect on human health.

Conclusion

The extracts of hibiscus leaves and potato peel can improve acceptability and shelf life of fermented orange juice summarized in the enhancement vitamin content,

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antioxidants profile, color, and sensory properties.

Author contributions

A.R.E.E.-H. and A.M.S.: Conceptualization; A.R.E.E.-H. and A.M.S.: Formal analysis; A.R.E.E.-H. and A.M.S.: Methodology; A.R.E.E.-H.: Statistical analysis of manuscript; A.R.E.E.-H. and G.A.E.-S.: Writing original draft and writing review and editing. All authors read and approved the final manuscript.

Conflicts of interest

All the authors declared that this is no conflict of interest in the study.

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References

Association of Official Analytical Chemists (AOAC). (2019). Official methods of analysis of AOAC international. 21st edition. AOAC International, Rockville, MD,USA.

Benavente-García O., Castillo J. (2008). Update on uses and properties of citrus flavonoids: new findings in anticancer, cardiovascular, and anti-inflammatory activity. *Journal of Agricultural and Food Chemistry*. 56: 6185-6205. [DOI: 10.1021/jf8006568]

Burca-Busaga C.G., Betoret N., Seguí L., Barrera C. (2022). Fermentation of clementine juice with *Lactobacillus salivarius* spp. *salivarius* CECT 4063: effect of trehalose addition and high-pressure homogenization on antioxidant properties, mucin adhesion, and shelf life. *Fermentation*. 8: 642. [DOI: 10.3390/fermentation8110642]

Canabarro N.I., Mazutti M.A., Ferreira M.D.C. (2019). Drying of olive (*Olea europaea* L.) leaves on a conveyor belt for supercritical extraction of bioactive compounds: mathematical modeling of drying/extraction operations and analysis of extracts. *Industrial Crops and Products*. 136: 140-151. [DOI: 10.1016/j.indcrop.2019.05.004]

Costa M.G.M., Fonteles T.V., De Jesus A.L.T., Rodrigues S. (2013). Sonicated pineapple juice as substrate for *L. casei* cultivation for probiotic beverage development: process optimisation and product stability. *Food Chemistry*. 139: 261-266. [DOI: 10.1016/j.foodchem.2013.01.059]

El-Hadary A.-A.R.E., Sulieman A.M., El-Shorbagy G.A. (2022). Comparative the antioxidants characteristics of orange and potato peels extracts under differences in pressure and conventional extractions. *Carpathian Journal of Food Science and Technology*. 14: 159-174. [DOI: 10.34302/crpjfst/2022.14.1.13]

González E.A., Agrasar A.T., Castro L.M.P., Fernández I.O., Guerra N.P. (2010). Production and characterization of distilled alcoholic beverages obtained by solid-state fermentation of black mulberry (*Morus nigra* L.) and black currant (*Ribes nigrum* L.). *Journal of Agricultural and Food Chemistry*. 58: 2529-2535. [DOI: 10.1021/jf9037562]

Gülçin I., Küfrevioğlu Ö.İ., Oktay M., Büyükokuroğlu M.E. (2004). Antioxidant, antimicrobial, antiulcer and analgesic activities of nettle (*Urtica dioica* L.). *Journal of Ethnopharmacology*. 90: 205-215. [DOI: 10.1016/j.jep.2003.09.028]

Hashemi S.M.B., Mousavi Khaneghah A., Barba F.J., Nemati Z., Sohrabi Shokofti S., Alizadeh F. (2017). Fermented sweet lemon juice (*Citrus limetta*) using *Lactobacillus plantarum* LS5: chemical composition, antioxidant and antibacterial activities. *Journal of Functional Foods*. 38: 409-414. [DOI: 10.1016/j.jff.2017.09.040]

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

Kun S., Rezessy-Szabó J.M., Nguyen Q.D., Hoschke Á. (2008). Changes of microbial population and some components in carrot juice during fermentation with selected *Bifidobacterium* strains. *Process Biochemistry*. 43: 816-821. [DOI: 10.1016/j.procbio.2008.03.008]

Kwaw E., Ma Y., Tchabo W., Apaliya M.T., Wu M., Sackey A.S., Xiao L., Tahir H.E. (2018). Effect of *Lactobacillus* strains on phenolic profile, color attributes and antioxidant activities of lactic-acid-fermented mulberry juice. *Food Chemistry*. 250: 148-154. [DOI: 10.1016/j.foodchem.2018.01.009]

Li H., Huang J., Wang Y., WangX., Ren Y., Yue T., Wang Z., Gao Z. (2021). Study on the nutritional characteristics and antioxidant activity of dealcoholized sequentially fermented apple juice with *Saccharomyces cerevisiae* and *Lactobacillus plantarum* fermentation. *Food Chemistry*. 363: 130351. [DOI: 10.1016/j.foodchem.2021.130351]

Min S., Jin Z.T., Min S.K., Yeom H., Zhang Q.H. (2003). Commercial-scale pulsed electric field processing of orange juice. *Journal of Food Science*. 68: 1265-1271. [DOI: 10.1111/j.1365-2621.2003.tb09637.x]

Mousavi Z.E., Mousavi S.M., Razavi S.H., Emam-Djomeh Z., Kiani H. (2011). Fermentation of pomegranate juice by probiotic lactic acid bacteria. *World Journal of Microbiology Biotechnology*. 27: 123-128. [DOI: 10.1007/s11274-010-0436-1]

Nade V.S., Kawale L.A., Dwivedi S., Yadav A.V. (2010). Neuroprotective effect of *Hibiscus rosa sinensis* in an oxidative stress model of cerebral post-ischemic reperfusion injury in rats. *Pharmaceutical Biology*. 48: 822-827. [DOI: 10.3109/13880200903283699]

Ordoñez A.A.L., Gomez J.D., Vattuone M.A., lsla M.I. (2006). Antioxidants activities of *Sechium edule* (Jacq.) Swartz extracts. *Food Chemistry*. 97: 452-458. [DOI: 10.1016/j.foodchem.2005.05.024]

Quan Q., Liu W., Guo J., Ye M., Zhang J. (2022). Effect of six lactic acid bacteria strains on physicochemical characteristics, antioxidant activities and sensory properties of fermented orange juices. *Foods*. 11: 1920. [DOI: 10.3390/foods11131920]

Škerget M., Kotnik P., Hadolin M., Hraš A.R., Simomič M., Knez Ž. (2005). Phenols, proanthocyanidins, flavones and flavonols in some plant materials and their antioxidants activities. *Food Chemistry*. 89: 191-198. [DOI: 10.1016/j.foodchem.2004.02.025]

Steel R.G.D., Torrie J.H., Dickey D.A. (1997). Principles and procedures of statistics: a biometrical approach. 3rd edition. McGraw-Hill, New York.

Sun Y., Wang Z., Wu J., Chen F., Liao X., Hu X. (2006). Optimising enzymatic maceration in pretreatment of carrot juice concentrate by response surface methodology. *International Journal of Food Science and Technology*. 41: 1082-1089. [DOI: 10.1111/j.1365-2621.2006.01182.x]

Vasudeva N., Sharma S.K. (2008). Biologically active compounds from the genus *Hibiscus*. *Pharmaceutical Biology*. 46: 145-153. [DOI: 10.1080/13880200701575320]

Vinderola C.G., Bailo N., Reinheimer J.A. (2000). Survival of probiotic microflora in Argentinian yoghurts during refrigerated storage. *Food Research International*. 33: 97-102. [DOI: 10.1016/S0963-9969(00)00011-9]

Wu C., Li T., Qi J., Jiang T., Xu H., Lei H. (2020). Effects of lactic acid fermentation-based biotransformation on phenolic profiles, antioxidant capacity and flavor volatiles of apple

[DOI: 10.18502/jfqhc.10.1.11988]

juice. *LWT - Food Science and Technology*. 122: 109064. [DOI: 10.1016/j.lwt.2020.109064]

Zaki E.F. (2022). Effect of adding lemongrass (*Cymbopogon citratus*) extract on quality characteristics of chicken burger during frozen storage. *Journal of Food Quality and Hazards Control*. 9: 181-189. [DOI: 10.18502/jfqhc.9.4.11373]

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