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Optimization and characterization of button mushroom (*Agaricus bisporus*) pickle production using apple vinegar

Mahsa Rakhshankhah[1], Fariba Zeynali[2], Saber Amiri[3*], Farnaz Nabizadeh[4]

1- MSc in Food Technology, Department of Food Science and Technology, Faculty of Agriculture, Urmia University, Urmia, Iran

2- Associate Professor, Department of Food Science and Technology, Faculty of Agriculture, Urmia University, Urmia, Iran

3- Associate Professor, Department of Food Science and Technology, Faculty of Agriculture, Urmia University, P.O. Box 57561–51818, Urmia, Iran

4- Institute of Agriculture, Water, Food, and Nutraceuticals, Mah.C., Islamic Azad University, Mahabad, Iran

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*Corresponding Author E-

sa.amiri@urmia.ac.ir

ABSTRACT

The aim of this study was to optimize the button mushroom (*Agaricus bisporus*) pickle formulation by using of apple vinegar and salt. For this purpose, effect of apple vinegar concentration (3, 4 and 5 % v/v), salt concentration (2,3 and 4 %w/v) and storage time (1, 10 and 19 days) on physicochemical properties of button mushroom including pH, acidity, nitrite content, color parameters, firmness and sensory characteristics was investigated. Analysis of variance showed that by increasing of vinegar and salt concentrations, pH and nitrite contents decreased, but acidity increased ($p<0.05$). L* decreased by elevation of salt and was developed during storage ($p<0.05$). Chroma index decreased by increasing of vinegar and was improve during storage ($p<0.05$). Required force for penetration in texture analysis, was developed by upgrading of apple vinegar and salt concentrations and storage time ($p<0.05$). Sensorial properties including flavor, texture and overall acceptance were improving by increasing of salt and vinegar levels but, color score was decreased ($p<0.05$) which was in agreement with color analysis. Finally, optimization of formula was carried out according to the desirability of studied characteristics and optimum formula was achieved including salt concentration of 2.963% (w/v), apple vinegar concentration of 3% (v/v) and storage time of 19 days.

1- INTRODUCTION

In recent years, demand for proteins especially herbal proteins has been increased with regard to population growth. One of the most important herbal proteins in man's diet are edible mushrooms [1]. Edible mushrooms have high nutritional value and contain 25 to 30% protein by dry weight that is almost equal to cereals and higher than fruits and vegetables [2]. Mushrooms are good source of some amino acids, vitamins and minerals. *Agaricus bisporus* from *Agaricaceae* family, a white button mushroom, is the most famous edible mushroom in the world. The nutritional content of button mushroom can be variable according to various cultivation conditions, growth stage, pre- and post-harvesting conditions. Button mushroom contains high moisture, its protein and carbohydrate contents are 11 to 29.1 and 51.1%, respectively [3]. This mushroom hold in 9 essential amino acids and is a source of non- starch polysaccharides (β-glucan, chitin and mannan), oligosaccharides, minerals (potassium, phosphorous, calcium, sodium, zinc, magnesium, iron, etc.) and D, C, B1, B2 and B3 vitamins [4]. Although button mushroom contains low percent of lipids, but it has some essential fatty acids such as linoleic acid. Button mushroom has bioactive components which their anti-cancer, anti- oxidant, anti- bacterial and anti- inflammatory properties have been proved [5]. Spoilage and quality loss occur in mushroom due to high moisture content, high respiration speed and loss of natural coating so, microorganisms, enzymatic reactions and biochemical changes during storage have main role in its shelf life [6]. Persistence of mushroom before that environmental factors affect its quality, is about 3 days [7]. Freezing, drying, canning and salting are common practices for mushroom protection. But some of these methods especially thermal processes (e.g. sterilization in brine) may change physicochemical properties of mushroom including color, flavor and nutritional content [8,9]. Likewise, today novel methods such as combination of gamma irradiation with fermentation to expand mushroom shelf life has been reported to be successful [7]. Fermentation or pickling is a way of food preservation which can be used to extend mushroom shelf life. The term pickling includes both lactic fermentation of food and also products that are acidified with adding of acetic acid [9]. Pickling of perishable food in vinegar along with salting leads to a ready to eat product that can be stored in room temperature in addition to its desirable flavor. In pickling, the appropriate salt concentration to extend shelf life and inhibit fungi, yeasts and bacteria growth, is very important [10]. Many researches have been carried out in the field of mushroom fermentation and starter utilization for fermentation. In an investigation *L. bulgaricus* was used for fermentation of *shimeji* mushroom and led to decrease of yeasts count, *Enterobacteriaceae* species and nitrite content and increase of lactic acid content. Sensorial properties of product were improved [11]. Fermentation of various mushrooms including *Termitomyces robustus, Agaricus bisporus, Boletus edulis, Auricularia auricularia, Cantharellus cibarus, Russula spp., Leccinum spp., Pleurotus spp* were studied [9]. Research in fermentation of white button mushroom in vinegar and salt is very limited. The aim of this paper is to use apple vinegar and salt to produce white button mushroom pickle, and then optimization of formula on the basis of physicochemical properties of product.

2- Materials and methods

White button mushroom was provided from a mushroom farm, apple vinegar was purchased from a credible factory and salt was achieved from a local market in Urmia, West Azarbaijan province, Iran.

1.1. Preparation of mushroom pickle

For preparation of mushroom pickle, acidifying procedure by using apple vinegar was applied. For this purpose, first mushrooms were sorted and almost similar sized mushrooms were selected. Then, they were cleaned, any contamination was eliminated and washed by cold water carefully. In next step, mushrooms were cut in two equal parts and blanched in boiling water (96 to 98 ˚C) for 2 min. Apple vinegar and salt were added according to statistical design. Then, filled with amount of 200 gr in glass jars and solution with proportion of 2/1 (solid/liquid) was added and sealed. The samples were stored for 19 days in ambient temperature. During the storage physicochemical properties of samples were investigated. Statistical design used in this study for preparation of mushroom pickle is shown in table 1.

Table 1: Experimental design on the basis of Box- Behnken design and three variables (apple vinegar, salt concentration, and storage time)

Run	A: Apple vinegar(%V/V)	B: Salt(%W/V)	C: Ripening Time (Day)
1	4	3	10
2	3	3	19
3	5	3	19
4	4	3	10
5	4	2	1
6	3	2	10
7	4	3	10
8	5	3	1
9	4	2	19
10	4	4	19
11	3	4	10
12	5	2	10
13	4	4	1
14	4	3	10
15	5	4	10
16	3	3	1
17	4	3	10

1.2.Chemical tests

For measurement of pH of samples, fluid part of samples and pH meter device were used (at 25 ˚C). Titrable acidity was measured through titration using NaOH (0.1 N). For this purpose, 20 cc of sample was weighed carefully. After adding a few drops of phenolphthalein, titration was carried out until stable pale pink color was appeared and acidity was calculated according to below equation [11]:

$$A = \frac{\mathrm{V} \times 0.0065 \times 100}{\mathrm{M}}$$

where A is acidity (%), V is consumed volume of NaOH (ml), M is sample weight (g).

1.3.Nitrite content

For measurement of nitrite content, Liu et al., (2016) procedure was applied with some modifications [9]. Mushroom samples were dehydrated initially, then grinded by meat grinder completely, and a homogenous pasty substance was achieved. 100 g of sample was weighed carefully. Then 100 cc distilled water was added to sample and weighed again. The sample was stirred until an absolute homogenous material was attained and then put in an ultrasonic bath for 30 min. In next step, the sample was filtered from a filter paper. The produced sample was centrifuged for 10 min in 5500 rpm. 0.1 cc sulfonamide (0.2 %

w/v) and 0.1 cc α- naphtylethylendiamine hydrochloride (0.1 % w/v) were added to 5 cc of achieved supernatant and sample was kept for 15 min in dark room. Then absorption of sample was measured by spectrometer at wavelength of 538 nm and nitrite concentration was evaluated from sodium nitrite standard curve. Finally, the achieved digit was multiplied in reverse dilution factor and nitrite concentration was obtained as mg of sodium nitrite per kg of initially diluted used sample. Solution without sample was applied as blank. For drawing standard curve, sodium nitrite was used.

1.4. Color analysis

For color analysis of samples lightness and chroma indexes were determined using a Chroma Meter CR 400 (Tokyo, Japan). L* reveals lightness of sample and is in the range of 0 (dark) to 100 (light) [12]. Chroma index was calculated according to following equation:

$$Chroma = (a^{*2} + b^{*2})^{1/2}$$

Chroma index demonstrates the saturating level or intensity of color and amounts of 0 and 60 show neutral and intense colors, respectively [13].

1.5. Texture analysis

Texture analysis was carried out using texture analyzer (TA. XT Plus, Stable Micro Systems, UK) in Urmia university. In texture analysis penetration test was applied. For this purpose, sample was located on the device in a manner that the cutting surface of mushroom was contacted to the surface of device. A cylindrical probe with 2 mm in diameter was applied. The penetration distance was 5 mm and test velocity was 1 mm/sec. Penetration force and probe replacement were measured with precision of 0.1 N and 0.001 sec, respectively. The maximum penetration force (Kg) was determined according to force- time curves [12].

1.6. Sensory analysis

Sensory evaluation was performed with 5-point hedonic test and sensorial attributes including color, texture, flavor and overall acceptance were investigated. 10 panelists were asked to evaluate samples with grading from very good (score- 5), good (4– score), medium (3- score), bad (2- score) and very bad (1- score) [14].

1.7. Statistical analysis

In this research, effect of apple vinegar concentration (3 to 5%), salt amount (2 to 4%) and storage time (1 to 19 days) on properties of mushroom pickle were investigated using Mixture design in form of Box- Behnken design. Statistical analysis of data was carried out using Regression analysis and ANOVA. Expert Design software version 11 was applied for analysis of data and graphing. Finally, optimum condition for production of mushroom pickle was achieved using numerical optimization and desirability function.

3-Results and discussion

pH and acidity

pH and acidity of samples were calculated as function of studies factors according to following models:

$$pH: 6.39 - 0.21\times A - 0.12\times B + 0.0076\times C$$
$R^2=0.76$ Adj $R^2=0.7$

$$Acidity: 0.067 + 0.012\times A + 0.012\times B + 0.001\times C$$
$R^2=0.74$ Adj $R^2=0.69$

The R^2 and the adjusted R^2 were desirable and Lack of fit was not significant. The results showed that apple vinegar concentration (A) and salt concentration (B) had significant effect on pH ($p<0.05$). Concentrations of apple vinegar and salt had considerable effect on acidity ($p<0.05$). While storage time (C) had no significant effect on acidity content ($p>0.05$). According to Fig.1 A and B by increasing of apple vinegar and salt concentrations pH decreased and by increasing of apple vinegar and salt amounts simultaneously, amount of acidity was developed from almost 0.13 to about 0.165 % (Fig.1 C). As apple vinegar contains acetic acid as an acidifier factor, is commonly used for food preservation so, with increase of its concentration pH value was dropped and

acidity was improved. Shahi et al., (2022) demonstrated that industrial apple vinegar in comparison with grape and jujube vinegars has minimum pH (2.97) and maximum acidity (5.31 % on the basis of acetic acid) [15]. McMurtrie et al., (2019) ehibited almost same results. They showed that in fermented cucumber using acetic acid in comparison with hydrochloric acid and without acid, speed of pH decrease in first 24 h was high [16].

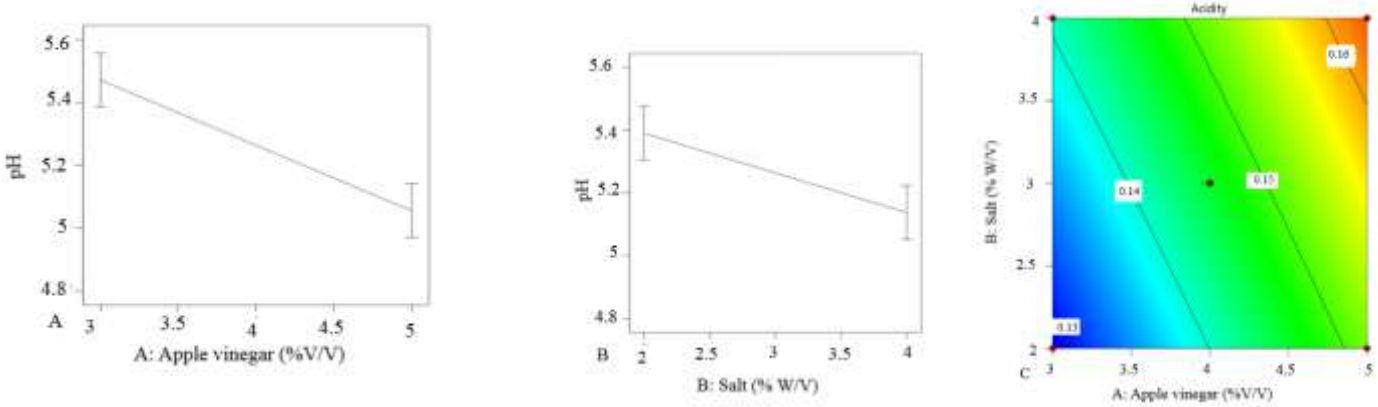


Figure 1: Effect of A: apple vinegar, B: salt concentrations on pH and C: effect of apple vinegar and salt concentrations on acidity of samples.

According to Fig.1 B, on 10th day of storage and apple vinegar concentration of 4% (v/v), by increasing of salt amount from 2 to 4 % (w/v), the pH decreased from 5.4 to 5.1. This is due to the fact that salt causes the intracellular extract and solution of cut mushrooms to bring out and as a result, lactic acid bacteria which are the responsible for spontaneously fermentation, were developed and more acid was produced and led to decrease of pH. The obtained results were in agreement with those of Viander et al., (2003). They produced sauerkraut by different salt concentrations including NaCl 0.5%, mineral salt 0.5% (containing NaCl 57% and KCl 28%) and NaCl 1.2% [17]. These results were also in agreement with those of Yang et al., (2020). They applied various concentrations of edible salt (0.5, 1.5, 2.5 and 3.5%) in sauerkraut production and analyzed the samples during 1 month. According to their results, in sauerkraut containing 2.5% salt, fermentation process was intense and optimum condition was provided for lactic acid bacteria metabolism and as a result these samples had lower pH [18]. Decrease of pH is related to organic acids production which are primitive metabolites of lactic acid bacteria [19]. Maskuri et al., (2025) and Hien et al., (2022), reported similar results for *shimeji* mushroom fermented with *Bifidobacterium* and *Kohlrabi* fermentation by different salt concentrations, respectively [19, 20].

Nitrite content

Nitrite content as a function of examined factors was achieved by following model:

$$\text{Nitrite content(mg/kg)}: 0.55 - 0.17\times A + 0.06\times B + 0.03\times C - 0.001\times C^2$$

$$\text{Adj } R^2=0.69 \quad R^2=0.77$$

According to ANOVA results, apple vinegar concentration and second-degree effect of storage time on nitrite content were significant ($p<0.05$). As shown in Fig.2, by expanding of apple vinegar concentration (A) from 3 to 5% (v/v), nitrite content was reduced from 0.45 to 0.1 mg/Kg, continuously. *Enterobacteriaceae* and some

other gram-negative bacteria, improve nitrite amount in product by reduction of nitrate to nitrite [11]. So, decrease of nitrite is related to decrease of nitrate reducing bacteria [21]. By rising of apple vinegar amount, pH was dropped and gram-negative bacteria growth was inhibited. As a result, *Enterobacteriaceae* as a gram-negative bacterium was not able to produce nitrite and its concentration was reduced [22]. Accumulation of nitrite in fermented food products can be a main problem. Extra nitrite in food products is harmful for health [23]. Salt concentration (B) and storage time (C) had no considerable effect on nitrite content ($p>0.05$).

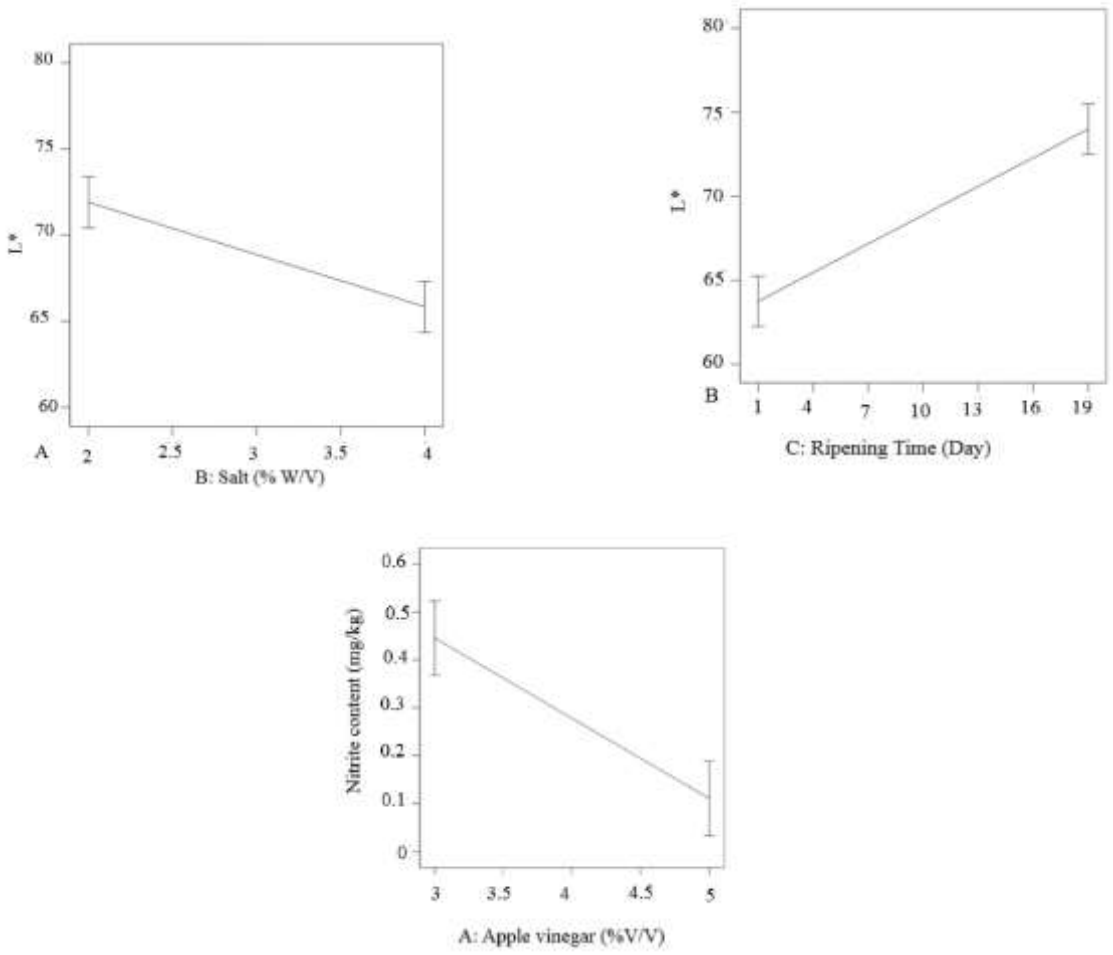


Figure 2: effect of apple vinegar concentration on nitrite content of samples.

Color

The amount of L* and chroma index as a function of studied factors were gained by following models:

Chroma(C^*): $31.67 + 1.88\times A - 6.46\times B - 0.09\times C - 0.93\times A\times B - 0.07\times A\times C + 0.1\times B\times C + 1.55\times B^2 + 0.01\times C^2$

Adj R^2=0.85 R^2=0.92

$L^*= 75.04 - 0.69\times A - 3.03\times B + 0.57\times C$

R^2=0.85 Adj R^2=0.8

The results revealed that apple vinegar concentration (A) had no significant effect on lightness (L*) of samples ($p>0.05$). while salt concentration affected the lightness of samples significantly ($p<0.05$). By increasing of salt concentration from 2

to 4% (w/v), lightness was reduced from almost 72 to 67, continuously (Fig.3 A).

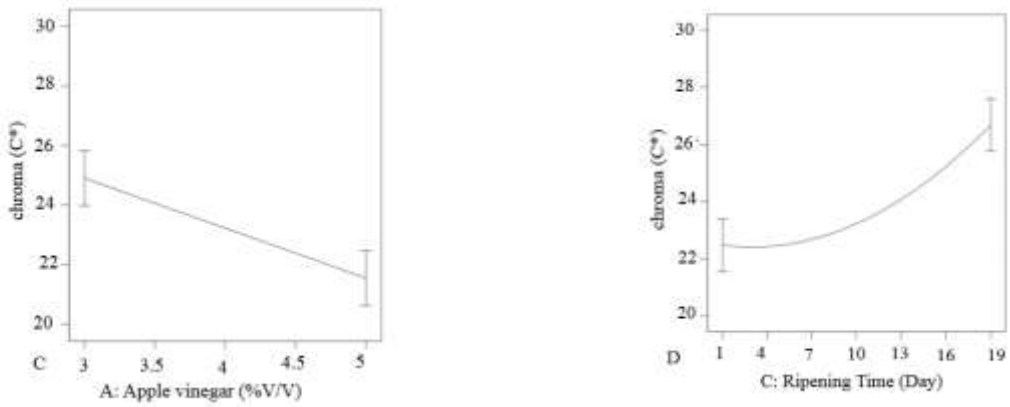


Figure 3: Effect of A: salt concentration and B: ripening time on L* C: Effect of apple vinegar concentration and D: ripening time on chroma of samples.

Storage time (C) affected lightness considerably, too ($p<0.05$). During storage from first to 19th day the lightness was improved from 64 to 74, continuously (Fig.3 B). Apple vinegar concentration (A) and storage time did not influence chroma significantly. By elevating of apple vinegar amount from 3 to 5% (v/v), chroma index was reduced from 25 to about 22 (Fig.3 C). during storage chroma index of samples was improved from 22.5 to 27 (Fig.3 D). Various factors can cause color changes in mushroom. Enzymatic activities including polyphenol oxidases, phenylalanine ammonia lyases and peroxidases, lead to improvement of browning. Moreover, *pseudomonas tolaasii* which is natural microflora of mushroom, can have similar affect [24,25]. Direct contact of mushroom surface with atmosphere and easily entrance of oxygen also cause oxidation reactions which lead to decrease of lightness [6]. Hence, various treatments have been applied to reduce activity of enzymes, bacteria and preventing from oxygen penetration to protect the color and lightness of mushroom. Applying different coatings has been tried by many researchers [2,6,13]. Karimi et al., (2015) used different coatings along with moisture absorbent materials including silica gel and sodium chloride for button mushroom treatment. They reported that the minimum lightness was related to the mushrooms which were treated by sodium chloride and their reason for this phenomenon was rapid absorption of moisture during first days of storage, saturation of salt and consequently couldn't be able to absorb more moisture [26]. In present assay, by improvement of salt amount, lightness was decreased which may be due to the effect of salt on extraction of intracellular solids especially phenolic materials and probably due to enzymatic reactions with bacterial origin. Because intracellular enzymes of mushrooms are inactivated during blanching. During storage lightness and chroma were developed which were probably due to replacement of salt and vinegar in mushroom texture. Venugopal et al., (2024) demonstrated that blanched mushrooms in 96- 98 ˚C water, showed higher L* and chroma and were lighter and brighter in appearance [27]. In our research blanching was carried out in similar condition.

Texture analysis

For evaluation of texture of samples maximum force required for penetration of probe in mushroom stalk was calculated. According to the results, apple vinegar concentration, salt amount, storage time, interaction effect of vinegar and salt and interaction effect of salt and storage time had significant effect on maximum required penetration force, on the other words strength of samples ($p<0.05$). The penetration force in stalk as a function of studied parameters was calculated by below model:

$$\text{Stalk Force(kg)} = -0.03 + 0.05\times A + 0.04\times B - 0.004\times C - 0.01\times A\times B + 0.002\times B\times C$$

$$\text{Adj } R^2=0.78 \qquad R^2=0.86$$

By increasing of apple vinegar concentration from 3 to about 4.4% (v/v) and salt concentration from 2 to 3.4% (w/v) simultaneously, the force was increased from 0.13 to 0.16 Kg. By improvement of apple vinegar concentration from 4.3 to 5% (v/v) and salt concentration from 3.4 to 4% (w/v), the force was raised from 0.16 to 0.17 Kg and then remained constantly (Fig.4). Maximum needed force for penetration is considered as firmness which is related to texture attributes well [28]. Mushroom texture softens during storage due to enzymatic activities and degradation of cell wall, damaging of parenchymal tissue and increasing of solubility of cell wall substances in intercellular fluid [13]. On the other hand, loss of moisture and dehydrating also lead to softening and destruction of texture. Vinegar prevented from softening and breaking down of cell wall by inhibiting of decomposer bacteria growth and protect texture strength so that by increasing vinegar concentration from 3 to 5% its protective effect against microorganisms was improved [29]. Zivanovic et al., (2000) demonstrated that maximum penetration force was decreased on 9th day of storage in fresh mushroom due to reduction of bacterial activities [29]. Cell wall of mushroom contrary to fruits and vegetables, loses pectin and is mainly composed of glucans, chitin and protein [30]. Chitin is the main structure of mushroom cell wall and forms 30- 50% of cell wall composition and is the major factor in strength and integrity of cell wall. Hardening of mushroom texture during storage is due to increase of chitin amount, while mushroom texture softening is related to increase of intercellular spaces in cap surface, shrinkage of stalk, destruction of central vacuole and decrease of protein and polysaccharides [31]. During storage, due to activity of some enzymes such as cellulases, chitinases and β- glucanases, cell wall constituents are decomposed and consequently, mushroom texture become soft [32,33]. Salt by inhibiting activity of softening enzymes, prevents from decrease of firmness in mushroom [34]. Generally, salt is added to fermented products to inhibit bacteria and avoid from softening of fruits and vegetables [35]. Moreover, salt prevents from aging by delaying of cell respiration. McMurtrie et al., (2016) reported that fermented cucumber produced with sodium chloride were harder than samples produced with calcium chloride [16].

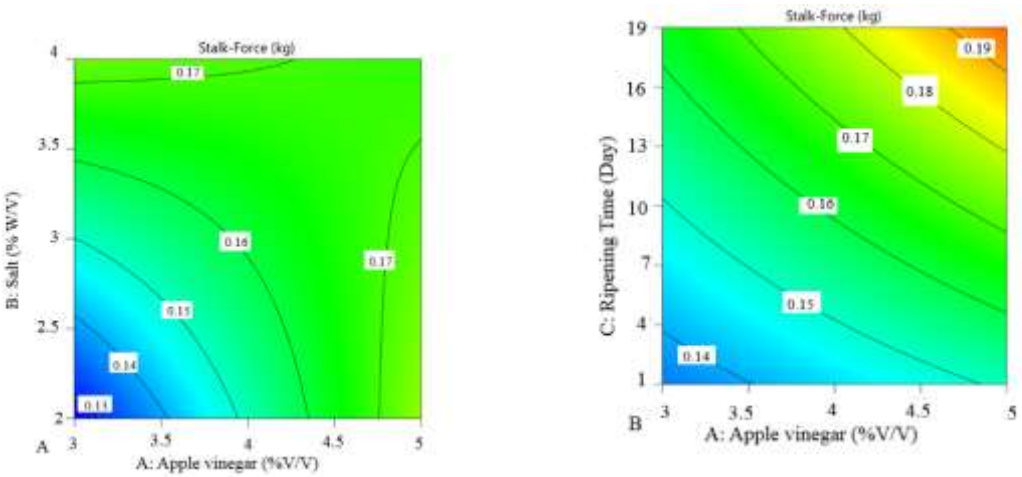


Figure 4: Effect of A: salt and apple vinegar concentrations, B: ripening time and apple vinegar concentrations on penetration force of samples.

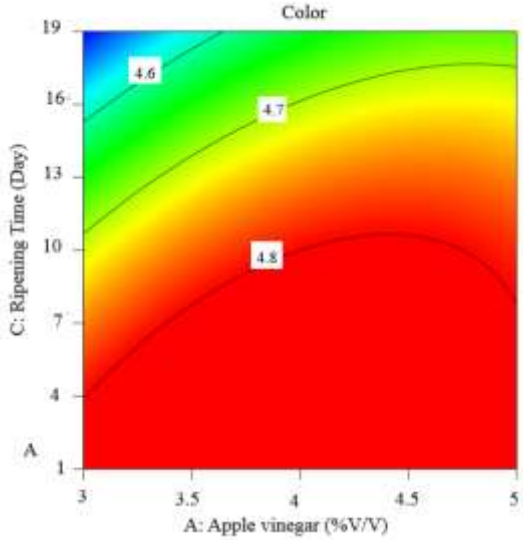
According to Fig.4, during 19 days of storage, the maximum force was increased from 0.135 to 0.165 Kg. Blanching of mushroom before pickling and fermentation leads to inactivation and reduction of activity of enzymes which are decomposer of cell wall and consequently, firmer product is produced [36]. Firmness is an indicator of quality of mushroom texture after harvesting and during storage. Alikhani-Koupaei et al., (2014) introduces firmness as changes in metabolic activities and moisture content [37]. Firmness of mushroom is a sign of quality, freshness and shelf life of mushroom and as a result can influence consumers satisfactory [38]. Bacterial enzymes can cause structural changes in texture and lead to shrinkage in cell walls. This phenomenon can be result of internal autolysins, too [29]. Hence, at higher levels of apple vinegar concentration, the mushroom samples had higher firmness on 19th day of storage and conserve their freshness and quality (Fig.4 B). In brined mushroom, blanching leads to decrease of intercellular spaces in cap and tight organization of cells in tissue which lead to increase of firmness in comparison with fresh mushroom [9]. Blanching causes mushroom texture to be firm and rubbery, removes internal air, inactivates enzymes and facilitates conditions for lactic acid bacteria growth [27].

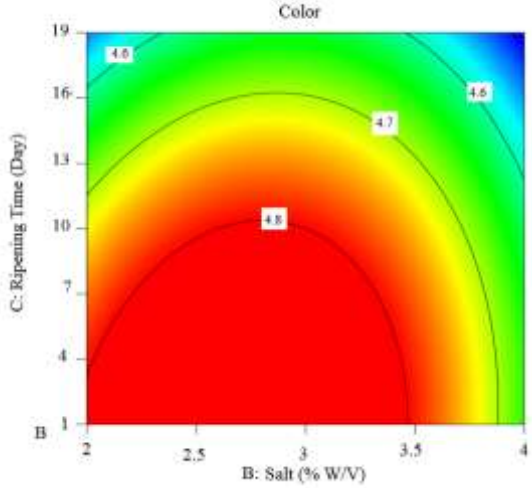
Sensory evaluation

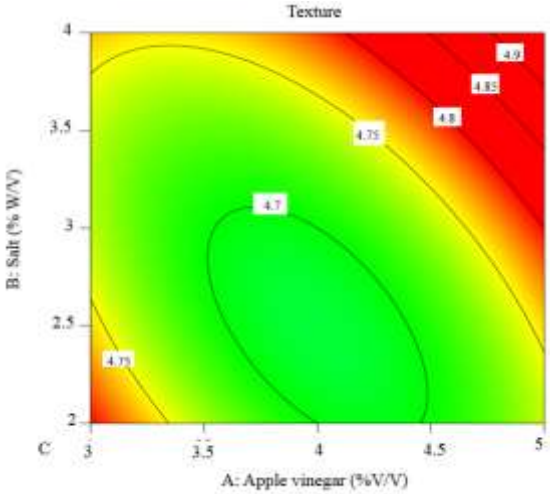
Sensory evaluation of color of samples as a function of studied factors was calculated by following model:

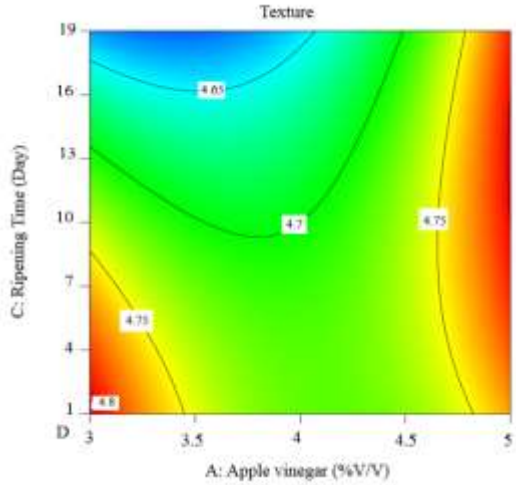
Color: $3.16 + 0.38\times A + 0.7\times B - 0.02\times C + 0.005\times A\times B - 0.05\times A^2 - 0.125\times B^2 - 0.0006\times C^2$

Adj R^2=0.91 R^2=0.95


Color
C: Ripening Time (Day)
A: Apple vinegar (%V/V)
A
4.6
4.7
4.8


Color
C: Ripening Time (Day)
B: Salt (% W/V)
B
4.6
4.7
4.8


Texture
B: Salt (% W/V)
A: Apple vinegar (%V/V)
C
4.9
4.85
4.8
4.75
4.7


Texture
C: Ripening Time (Day)
A: Apple vinegar (%V/V)
D
4.7
4.75

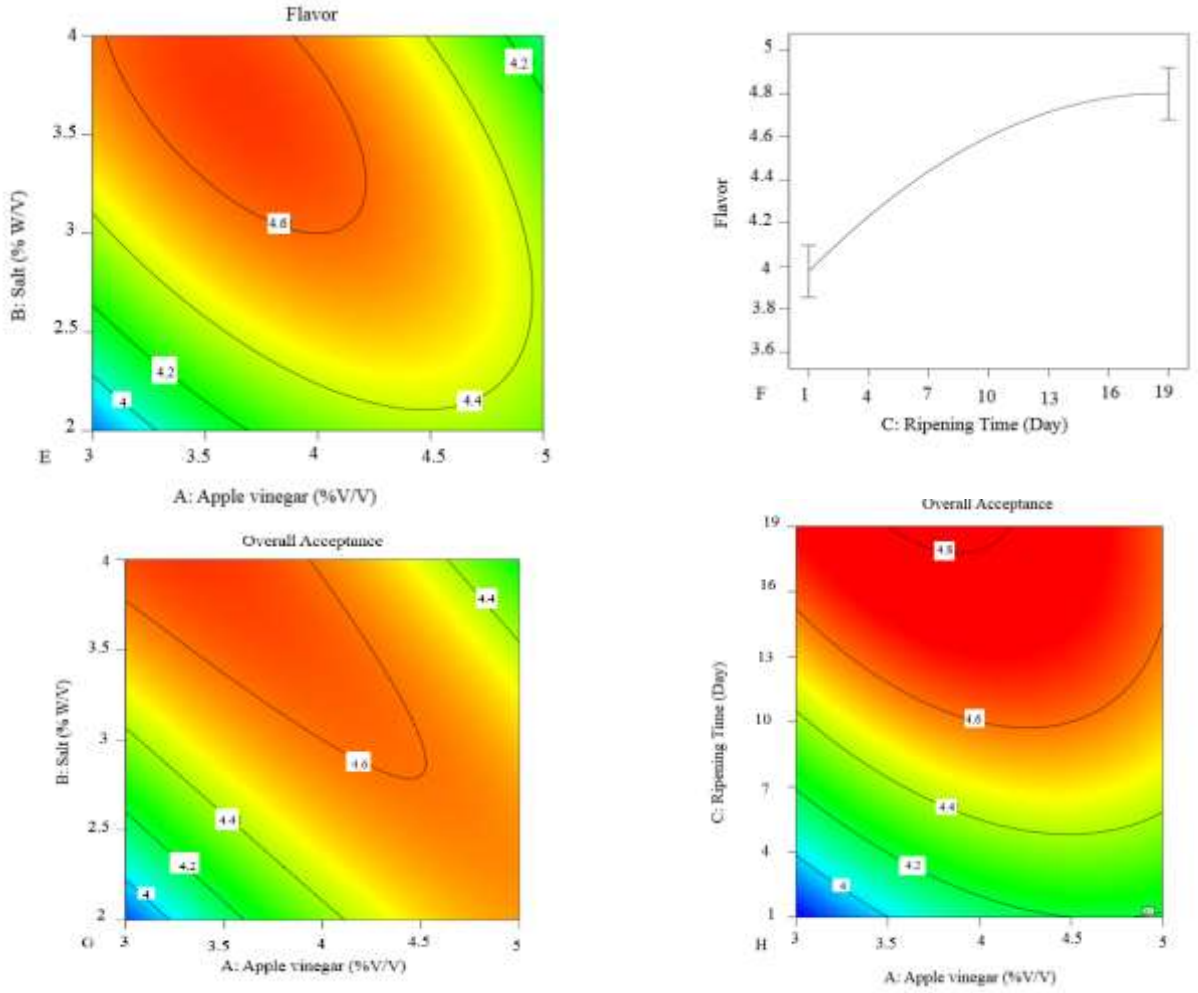


Figure 5: Effect of salt and apple vinegar concentrations, ripening time on A and B: color, C and D: texture, E and F: flavor, G and H: overall acceptance scores of samples.

As it is illustrated in Fig.5. A, in final days of storage at high levels of apple vinegar concentration, color score was high and at low levels of apple vinegar concentration it was low. At the end of storage time, samples with high salt concentration gained low color score (Fig.5 B). In analysis of lightness, salt concentration had negative effect on lightness of samples, too (Fig.3 A). In general, color score of samples were dropped from 10^{th} day of storage.

Texture score of samples as a function of studied parameters was achieved by below model:

Texture: $6.84 - 0.76\times A - 0.44\times B - 0.01\times C + 0.06\times A\times B + 0.005\times A\times C - 0.003\times B\times C + 0.07\times A^2 + 0.04\times B^2 - 0.0002\times C^2$

Adj R^2=0.68 R^2=0.87

By increasing of apple vinegar and salt concentrations, texture score of samples was improved (Fig.5 C) which is in agreement with texture analysis results. As it was stated in above, by expanding of salt and apple vinegar concentrations, firmness of samples was raised. Also, at the end of storage time, samples with high concentration of apple vinegar, achieved high texture score (Fig.5 D).

Flavor score of samples as a function of studied factors was calculated by following model:

Flavor: $0.99 + 1.75\times B + 0.1\times C - 0.14\times A\times B + 0.04\times A^2 - 0.18\times B^2 - 0.003\times C^2$ Adj R^2=0.85 R^2=0.91

Samples with elevated salt and apple vinegar concentrations, gained high flavor score (Fig.5 E). By decreasing of salt concentration, flavor score was dropped as well. Apple vinegar concentration had no significant effect on flavor score of samples. Improvement of flavor is one of the aims of addition of salt in fermented products [35]. During storage flavor score was improved (Fig.5 F). Balancing of flavor during storage causes flavor to be improved. Vinegar is a fermented product which is obtained from sugary substances fermentation and contains bioactive materials such as phenolic components, amino acids and organic acids, all of which are effective in improvement of final flavor [15]. In spontaneously fermentation (pickling) which is carried out by adding vinegar (or acetic acid) and salt, the product is kept at room temperature until natural microflora become dominant in media. Dominant microflora in these products are lactic acid bacteria. Metabolites of microflora metabolism have also major role in final flavor of product [9].

Overall acceptance of samples was achieved from below model:

Overall acceptance: $-3.95 + 2.24\times A + 1.96\times B + 0.12\times C - 0.27\times A\times B - 0.014\times A\times C - 0.15\times A^2 - 0.125\times B^2 - 0.0015\times C^2$ Adj R^2=0.95 R^2=0.97

Samples with high concentration of apple vinegar gained higher overall acceptance score (Fig.5 G, H).

Optimization and desirability

The aim of optimizing was to achieve optimum amounts of apple vinegar, salt and storage time for production of mushroom pickle in which pH and nitrite contents are minimum and acidity, lightness and chroma indexes, texture firmness and overall acceptance score are maximum. According to the obtained results from statistical analysis of samples, the optimum amounts of examined variables for achieving maximum desirability were 5.5 for pH, 0.395 mg/Kg for nitrite content, 0.147% for acidity, 73.71 for lightness, 28.36 for chroma, 0.161 Kg for penetration force and 4.7 for overall acceptance score. Moreover, overall desirability for all variables was obtained 0.932. According to the results, optimum amounts of apple vinegar, salt concentration and storage time with maximum desirability were 3% (v/v), 2.963% (w/v) and 19 days, respectively.

4-Conclusion

In present research, the effects of apple vinegar concentration, salt amount and storage time on physicochemical properties of button mushroom was investigated. Obtained results from ANOVA revealed that studied variables had significant effect on physicochemical properties of samples. So that, acidity of samples was increased under influence of vinegar and salt. Nitrite content of samples was reduced due to inhibitory effect of vinegar and salt on microorganisms especially the nitrite producer species. Also, vinegar and salt cause the texture to improve by inhibiting of enzymatic activities and microbial growth. The results of this assay showed that lightness and chroma index of samples were decreased by increasing of apple vinegar and salt concentrations which was probably due to exit of soluble internal substances and activity of microbial enzymes. In sensory evaluation, sensorial attributes of samples were influenced by applied treatments and improved. Optimum formula for mushroom pickle was determined by considering of studied properties.

Data availability

Data will be available on request.

Conflict of Interest

The authors confirm that they have no conflicts of interest in this study.

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Authors Contributions

Mahsa Rakhshankhah: investigation, data collection, data analysis

Fariba Zeynali: management of investigation, methodology, data analysis

Saber Amiri: methodology, data analysis, software

Farnaz Nabizadeh: writing, reviewing, literature review

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مقاله علمی_پژوهشی

بهینه‌سازی و مشخصه‌یابی تولید ترشی قارچ دکمه‌ای (*Agaricus bisporus*) با استفاده از سرکه سیب

مهسا رخشانخواه[۱]، فریبا زینالی[۲]، صابر امیری[۳*]، فرناز نبی زاده[۴]

۱- دانش آموخته کارشناسی ارشد علوم و صنایع غذایی، گروه علوم و مهندسی صنایع غذایی، دانشکده کشاورزی، دانشگاه ارومیه، ارومیه، ایران.

۲- دانشیار گروه علوم و مهندسی صنایع غذایی، دانشکده کشاورزی، دانشگاه ارومیه، ارومیه، ایران

۳- دانشیار گروه علوم و مهندسی صنایع غذایی، دانشکده کشاورزی، دانشگاه ارومیه، ارومیه، ایران

۴- دانشکده کشاورزی، آب، غذا و فراسودمندها، واحد مهاباد، دانشگاه آزاد اسلامی، مهاباد، ایران

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* مسئول مکاتبات:

sa.amiri@urmia.ac.ir

چکیده

هدف از این پژوهش بهینه‌سازی فرمول تولید ترشی قارچ دکمه‌ای (*Agaricus bisporus*) با استفاده از سرکه سیب و نمک می‌باشد. برای این منظور، تاثیر سرکه سیب در سه سطح (۳، ٤ و ٥ درصد)، غلظت نمک در سه سطح (۲، ۳ و ٤ درصد) و زمان نگهداری در سه سطح (۱، ۱۰ و ۱۹ روز) بر ویژگی‌های فیزیکوشیمیایی قارچ دکمه‌ای شامل pH اسیدیته، میزان نیتریت، پارامترهای رنگ، سفتی و ویژگی‌های حسی بررسی شد. نتایج حاصل از آنالیز داده‌ها نشان داد که با افزایش مقدار سرکه و نمک مقادیر pH و نیتریت کاهش واسیدیته افزایش یافت ($p<0.05$). پارامتر L* با افزایش غلظت نمک کاهش و طی نگهداری افزایش یافت و شاخص کروما با افزایش غلظت سرکه سیب کاهش و طی نگهداری افزایش یافت ($p<0.05$). مقدار نیروی لازم برای نفوذ در بافت‌سنجی، با افزایش سطوح نمک و سرکه و طی نگهداری افزایش یافت ($p<0.05$). ویژگی‌های حسی شامل طعم، بافت و پذیرش کلی نمونه‌ها با افزایش غلظت نمک و سرکه افزایش یافتند و لی امتیاز رنگ کاهش یافت($p<0.05$) که مطابق با نتایج رنگ سنجی بود. در نهایت، براساس مطلوبیت این خصوصیات، بهینه سازی فرمول انجام گرفت و فرمول بهینه ترشی قارچ بصورت غلظت نمک برابر ۲/۹٦۳ درصد وزنی–حجمی، غلظت سرکه سیب ۳ درصد حجمی–حجمی و زمان نگهداری ۱۹ روز به دست آمد.