Effect of Chemical Preservatives on the Shelf Life of Hummus during Different Storage Temperatures

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ABSTRACT

Different levels of potassium sorbate (PS), sodium benzoate (SB) and sodium metabisulfite (SM) were added individually or in combinations to hummus, which was acidified to pH 4.5, before storage at 5, 10 and 15°C. Addition of 0.05% and 0.1 % PS increased the shelf life of hummus to 35 and 49 days, respectively, while it was 15 days for the control hummus without preservatives. The concentrations 0.1% and 0.15 % of SB were needed to achieve the same shelf life of PS treated hummus. Sodium metabisulfite was the most effective preservative since adding 0.05% and 0.1% was associated with shelf lives of 63 and 77 days, respectively. Combinations of 0.05% of each of SM and PS and of ≥ 0.05% SM and ≥ 0.15% SB extended the shelf life of hummus to > 90 days. Keeping hummus at 10 and 15°C reduced the shelf life for all levels and types of preservatives used. Lactic acid bacteria (LAB) formed the predominant microorganisms at the spoilage onset for the control, PS and SB treated hummus; *Enterobacteriaceae* and both yeasts and molds remained significantly ($p \leq 0.05$) at lower counts than LAB. In all SM treatments, LAB, yeasts and molds were predominant while *Enterobacteriaceae* remained at significantly ($p \leq 0.05$) lower counts.

Keywords: Hummus, Shelf life, Potassium sorbate, Sodium benzoate, Sodium metabisulfite, Chemical preservatives.

INTRODUCTION

Hummus is considered one of the most popular traditional foods in Middle East countries such as Jordan, Syria and Lebanon. It is prepared from dried chickpeas (*Cicer arietinum* L.) and tahina (an oily viscous fluid obtained by milling dehulled roasted white sesame seeds). Hummus is made from 20-25 % of boiled chickpea, lemon juice or citric acid, garlic and salt (Yamani and Al-Dababseh, 1994). The processing steps for hummus preparation include chickpeas soaking in water for overnight, then boiling with a sodium bicarbonate aqueous solution until getting soft texture, followed by blending with tahina and other ingredients to obtain the basic smooth chickpea mix (Faris and Takruri, 2002). During the preparation procedure, hummus is vulnerable to bacterial cross contamination from ingredients, utensils and the environment. Except for boiling of the chickpeas, there is no heat treatment during preparation and no chemical preservative is added. These conditions limit the shelf life of hummus to 24-72h under refrigerated temperature (Yamani and Al-Dababseh, 1994). Consequently, this short shelf life limits the large scale production of hummus to the home level or to local production to be sold and consumed

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within 2-3 days. Hummus is normally stored at refrigeration after preparation, but it may be exposed to higher temperatures during mishandling and serving which may reduce its shelf life.

Hummus is highly suitable for the growth of a wide range of microorganisms, including spherical LAB, such as *Lactococcus*, *Enterococcus* and *Leuconostoc,* yeasts and members of *Enterobacteriaceae* (Yamani and Al-Dababseh, 1994). This could be associated with the intrinsic conditions of hummus including relatively low pH (about 5.1), high a_w (above 0.98) and high concentration of oligosaccharides (Singh et al., 2004; Yamani and Al- Dababseh, 1994). LAB represent the predominant microorganisms due to thier capability for rapid metabolism of sugars and producing lactic acid. Spoiled hummus has a strong sour flavor and a watery texture (Yamani and Al-Dabasheh, 1994).

Different methods have been developed for the preservation of hummus such as canning and carton packaging (Amr and Yaseen, 1994). Potassium sorbate and sodium metabisulfite preservatives are GRAS (generally recognized as safe) compounds (FDA, 2001).The maximum permitted levels of benzoic and sorbic acids and their salts in foods are 0.1 % and 0.2 %, respectively and the maximum permitted level is 0.1 % for sodium metabisulfite (Chipley, 2005; Stopforth et al., 2005; FDA, 2010). Benzoic acid is a natural compound, which is present at low levels in fermented dairy products (Mihyar et al., 1999). Sorbate and benzoate salts proved to be efficient antimicrobial compounds, especially in acidic foods such as labaneh and black olives that are normally spoiled by yeasts and molds (Mihyar et al., 1997; Turantaş et al., 1999; Scotter and Castle, 2004). Sodium metabisulfite has been used to extend the shelf life of foods including meat, fruit and dairy products, and it is effective in inhibiting growth and multiplication of a wide range of microorganisms including gram negative and gram positive bacteria and yeasts including the preservative resistant species of *Zygosaccharomyces* (Jay et al., 2005). In addition to antimicrobial activity, SM is commonly used in foods as antioxidants preventing vitamins and color oxidation (Henderson, 2009).

This study was carried out to investigate the feasibility of producing microbiologically stable hummus using PS, SB and SM preservatives, in addition to determination of types and counts of microorganisms responsible for termination of the shelf life of hummus under several storage temperatures.

MATERIALS AND METHODS

Hummus Samples

Commercial hummus was obtained from Hamada Restaurants (Amman, Jordan). Ten kilograms of hummus were collected directly after preparation from its ingredients (chickpea, tahina, salt and citric acid) in the form of a soft paste, kept at 5° C and used within 4 h.

Acidification

The initial pH of hummus was measured using a pH-meter (Hanna Instruments, Limena, Padova, Italy) and was recorded as 5.3. The pH was gradually lowered to 4.5 with mixing using a stock citric acid solution (10 % w/v). The amount of citric acid added was about 50 ml of the solution to the 10 kilograms of hummus used. Reducing the pH of hummus was performed to increase the efficiency of the preservatives.

Preparation of Preservative Concentrations

Fifty gram portions of hummus without preservatives (4.5 pH) were distributed into press-to-seal plastic containers (50 g capacity). Stock preservatives solutions were prepared by dissolving 3.13 g of each preservative in 50 ml of sterilized distilled water to obtain a concentration

of 6.26 % w/v. The preservatives used were potassium sorbate (PS), sodium benzoate (SB) and sodium metabisulfite (SM). Different levels of preservatives in hummus were prepared by adding different levels of the preservative containing stock solution to the hummus containers to obtain final concentrations of 0.05, 0.1, 0.15 and 0.2 % as shown in Table 1. Combinations of (PS + SM) and (SB + SM) at different levels were prepared in hummus to study the effect of combined preservatives (Table 1). After the addition of the stock solution, hummus was properly mixed by sterilized glass rods and the contents of each plastic container were made up to 52.8 g by adding sterilized distilled water as shown in Table 1. A control sample was prepared by mixing 50 g hummus and 2.8 ml of sterilized distilled water. Twenty four containers were prepared for each preservative treatment. These were then divided into three groups (each of eight containers) and each was stored at 5, 10 or 15 °C. Three containers were used for direct microscopic examination and for microbial examination, while the other five were used for sensory analysis.

Table 1. Preparation of hummus at different levels of potassium sorbate (PS), sodium benzoate (SB) and sodium metabisulfite (SM) in commercial hummus.

Sample	Preservative level (% w/w)			ml*/sample			Distilled water (ml)
	PS	SB	SM	PS	SB	SM	
1	0.05	0.00	0.00	0.4	0.0	0.0	2.4
2	0.10	0.00	0.00	0.8	0.0	0.0	2.0
3	0.15	0.00	0.00	1.2	0.0	0.0	1.6
4	0.00	0.10	0.00	0.0	0.8	0.0	2.0
5	0.00	0.15	0.00	0.0	1.2	0.0	1.6
6	0.00	0.20	0.00	0.0	1.6	0.0	1.2
7	0.00	0.00	0.05	0.0	0.0	0.4	2.4
8	0.00	0.00	0.10	0.0	0.0	0.8	2.0
9	0.00	0.00	0.15	0.0	0.0	1.2	1.6
10	0.05	0.00	0.05	0.4	0.0	0.4	2.0
11	0.05	0.00	0.10	0.4	0.0	0.8	1.6
12	0.05	0.00	0.15	0.4	0.0	1.2	1.2
13	0.10	0.00	0.05	0.8	0.0	0.4	1.6
14	0.10	0.00	0.10	0.8	0.0	0.8	1.2
15	0.10	0.00	0.15	0.8	0.0	1.2	0.8
16	0.15	0.00	0.05	1.2	0.0	0.4	1.6
17	0.15	0.00	0.10	1.2	0.0	0.8	1.2

Sample	Preservative level (% w/w)			ml*/sample			Distilled water (ml)
	PS	SB	SM	PS	SB	SM	
18	0.15	0.00	0.15	1.2	0.0	1.2	0.8
19	0.00	0.10	0.05	0.0	0.8	0.4	1.6
20	0.00	0.10	0.10	0.0	0.8	0.8	1.2
21	0.00	0.10	0.15	0.0	0.8	1.2	0.8
22	0.00	0.15	0.05	0.0	1.2	0.4	1.2
23	0.00	0.15	0.10	0.0	1.2	0.8	0.8
24	0.00	0.15	0.15	0.0	1.2	1.2	0.4
25	0.00	0.20	0.05	0.0	1.6	0.4	0.8
26	0.00	0.20	0.10	0.0	1.6	0.8	0.4
27	0.00	0.20	0.15	0.0	1.6	1.2	0.0
Control	0.00	0.00	0.00	0.0	0.0	0.0	2.8

*Stock solution of 3.13 g of the particular preservative in 50 ml of sterilized distilled water (6.26 % w/v).

Direct Microscopic Examination

Direct microscopic examination of hummus was performed on a daily basis during the storage period. Smear samples were collected from triplicate containers for each treatment using a 3 mm wire loop. The smears were heat fixed and stained using Loeffler′s methylene blue for 5 min (Vanderzant and Splittstoesser, 2001). The smears were tested using the oil lens of a phase contrast microscope (Olympus CX21, Hamburg, Germany). The average number of fields examined was 10-12 fields. Total microbial load of hummus was described as high, moderate, low or not detected when the average numbers of cells per field were over 50, 25-49, 1-24 and less than 1, respectively. Samples identified with high levels of microorganism cells were further subjected to sensory analysis.

Sensory Analysis

Sensory analysis was conducted on hummus according to Hedegaard et al. (2006). Five trained panelists conducted the test in an odor-free, good lightened and quite room. Samples were presented in plastic containers for each panelist, and each was provided a sterilized glass rod for sample mixing during testing. The samples were taken out of the incubator and kept at room temperature for 15 min prior to analysis. Each sample was categorized into acceptable or unacceptable according to the presence or absence of moldy smell and change in appearance (color, texture and gas production). Samples categorized unacceptable were considered as having reached the end of the shelf life.

Microbiological Examination

Samples were analyzed in triplicates, for aerobic plate count and the counts of LAB, *Enterobacteriaceae*, both of yeasts and molds, in order to determine the type of microorganism responsible for the spoilage. The pour

plate technique was used for determining baseline microbial enumerations for hummus just after the acidification phase and before the addition of preservatives. Aerobic plate count and the counts of both of yeasts and molds were made according to the procedure of FDA's Bacteriological Analytical Manual (AOAC, 2000). The enumerations of *Enterobacteriaceae* and lactic acid bacteria were carried out as described by Vanderzant and Splittstoesser (2001).

Statistical Analysis

The statistical analytical system (SAS Institute Inc., Cary, N. C.) package (version 8.2) was used to compare triplicate means of the microbial numbers for each treatment. A significance level of 5 % was used for all comparisons.

RESULTS

Initial Microbial Counts

The average initial aerobic plate count of hummus directly after acidification and prior to preservative addition was 7.2×10^4, while the average counts of LAB, both of yeasts and molds and *Enterobacteriaceae* were 2.1×10^4, 1.0×10^3 and 1.4×10^2, respectively. LAB were the predominant microorganisms contaminating hummus followed by both of yeasts and molds, then by *Enterobacteriaceae*.

Effect of Chemical Preservatives on the Shelf Life of Hummus

Table 2 shows the effect of different levels of preservatives on the shelf life of hummus at different temperatures. Results showed that the addition of PS at the levels of 0.05% and 0.1% extended the shelf life of hummus to 35 and 49 days. Sodium benzoate at higher levels (0.1% and 0.15%) extended the shelf life to the same length, 35 and 49 days, respectively. Using SM at 0.05% and 0.1 % extended the shelf life up to 63 and 77 days, respectively representing the best treatment when preservatives were used individually. Combined treatments consisting of SM and PS reacted synergistically in order to extend shelf life of hummus, because theses treatments left hummus unspoiled for > 90 days at the lowest (0.05%) level used from each of them, whereas a shorter shelf life (< 90 days) was obtained by using each of them individually at 0.1% level (Table 2). Treatments consisting of both SB and SM demonstrated an antagonistic interaction because combined 0.1 % SB and 0.05 % SM caused a shelf life of 42 days while using 0.15% of either SP or SM extended the shelf life to 49 days and > 90 days, respectively (Table 2).

Table 2. Shelf life (days) of hummus containing different levels of preservatives during storage at 5, 10 and 15 °C.

Preservative*	Concentration (%)	Storage temperature (°C)		
		5	10	15
PS	0.05	35**	13	9
	0.10	49	15	11
	0.15	NS***	20	18
SB	0.10	35	7	4
	0.15	49	11	7
	0.20	89	18	11

Preservative*	Concentration (%)	Storage temperature (°C)		
		5	**10**	**15**
SM	0.05	63	11	9
	0.10	77	49	25
	0.15	NS	56	32
PS + SM	0.05 + 0.05	NS	NS	NS
	0.05 + 0.10	NS	NS	NS
	0.05 + 0.15	NS	NS	NS
	0.10 + 0.05	NS	NS	NS
SB + SM	0.10 + 0.05	42	7	7
	0.10 + 0.10	84	13	11
	0.10 + 0.15	NS	25	13
	0.15 + 0.05	NS	NS	NS
	0.15 + 0.10	NS	NS	NS
Control	0.0	15	4	4

* Preservatives were potassium sorbate (PS), sodium benzoate (SB) and sodium metabisulfite (SM).

** Days at which high microbial counts and unacceptable changes in smell and appearance were noticed.

***NS: No signs of spoilage were noticed after 90 days of incubation.

Effect of Storage Temperature on the Shelf Life of Hummus

Increasing the storage temperature from 5 to 10 and to 15 °C decreased the shelf life of hummus for individual and combined preservative treatments of SB and SM (Table 2). Increasing storage temperature did not cause earlier termination of the shelf life of treated hummus with combined PS and SM at all levels (Table 2).

Microbial Counts of Hummus at the End of the Shelf Life

LAB had significantly ($p \leq 0.05$) the highest microbial count at the spoilage time in the control hummus (without preservatives) (Table 3) as well as in PS and SB treated hummus (Table 3). The counts of *Enterobacteriaceae* and both of yeasts and molds were significantly lower ($p \leq 0.05$) than the LAB counts. Regarding the effect of storage temperature, both of yeasts and molds had relatively higher contribution as spoilage flora in hummus kept at the lower storage temperature (5° C) than in that kept at higher temperatures (10 and 15 °C) for the control and SB treatments (Table 3). For SM treated hummus, alone and in combinations, LAB and both of yeasts and molds reached significantly ($p \leq 0.05$) higher counts at the spoilage time, while *Enterobacteriaceae* had significantly ($p \leq 0.05$) lower counts (Tables 3 and 4). The effect of storage temperature in selecting the type of spoilage microorganism was less apparent in SM treated samples (Tables 3 and 4).

Table 3. Aerobic plate count (APC) and counts of lactic acid bacteria (LAB), *Enterobacteriaceae* (Ent), both of yeasts and molds (Y & M) at the day of spoilage onset in hummus without preservative (control) and at different levels of potassium sorbate (PS), sodium benzoate (SB) and sodium metabisulfite (SM) at different storage temperatures.

% Preservative/ Temp.	Detected spoilage days	Count (Log_{10} CFU/g)			
		APC	LAB	Ent	Y & M
Control					
0.0/ 5 ºC	15	8.70± 0.01 [a*]	7.90± 0.10 [a]	3.99 ± 0.08 [c]	6.77 ± 0.12 [a]
0.0/ 10 ºC	4	7.75 ± 0.12 [a]	6.70 ± 0.09 [ab]	2.17 ± 0.02 [c]	5.85 ± 0.10 [b]
0.0/ 15 ºC	4	7.96 ± 0.15 [a]	7.60 ± 0.07 [a]	2.11 ± 0.01 [c]	4.95 ± 0.09 [b]
PS					
0.05 /5	35	7.48 ± 0.12 [a]	7.08 ± 0.13 [a]	2.85 ± 0.10 [c]	4.08 ± 0.01 [b]
0.1 /5	49	8.30 ± 0.15 [a]	7.84 ± 0.01 [a]	<1.00 ± 0.01 [c]	5.70 ± 0.02 [b]
0.15 /5			NS[**]		
0.05 /10	13	6.15 ± 0.07 [a]	5.76 ± 0.03 [b]	2.28 ± 0.12 [d]	4.45 ± 0.05 [c]
0.1 /10	15	6.34 ± 0.03 [a]	6.30 ± 0.07 [a]	2.30 ± 0.06 [b]	3.15 ± 0.18 [b]
0.15 /10	20	7.38 ± 0.11 [a]	6.87 ± 0.12 [b]	2.08 ± 0.09 [c]	2.38 ± 0.10 [c]
0.05 /15	9	7.83 ± 0.05 [a]	7.08 ± 0.05 [a]	3.82 ± 0.02 [b]	3.92 ±0.09 [b]
0.1 /15	11	6.77 ± 0.16 [a]	5.96 ± 0.03 [a]	2.18 ± 0.10 [b]	2.48 ± 0.02 [b]
0.15 /15	18	8.92 ± 0.02 [a]	7.92 ± 0.07 [a]	2.76 ± 0.08 [c]	3.96 ± 0.08 [b]
SB					
0.1 /5	35	7.41 ±0.08 [a]	6.90 ± 0.07 [a]	2.96 ± 0.03 [b]	5.98 ± 0.03 [a]
0.15 /5	49	6.50 ± 0.01 [a]	6.23 ± 0.08 [a]	3.71 ± 0.06 [c]	5.88 ± 0.08 [b]
0.2 /5	89	7.78 ± 0.07 [a]	7.48 ± 0.03 [a]	3.04 ± 0.08 [b]	6.75 ± 0.16 [a]
0.1 /10	7	8.15 ± 0.10 [a]	7.90 ± 0.12 [a]	1.98 ± 0.01 [c]	3.26 ± 0.02 [b]
0.15 /10	11	7.32 ± 0.08 [a]	6.54 ± 0.08 [a]	1.83 ± 0.04 [c]	4.03 ± 0.11 [b]
0.2 /10	18	7.95 ± 0.09 [a]	7.01 ± 0.07 [a]	2.57 ± 0.08 [b]	3.48 ± 0.18 [b]
0.1 /15	5	7.51 ± 0.11 [a]	6.78 ± 0.08 [a]	2.60 ± 0.07 [c]	3.83 ± 0.10 [b]
0.15 /15	7	6.59 ± 0.08 [a]	6.51 ± 0.04 [a]	3.08 ± 0.03 [b]	2.38 ± 0.09 [b]
0.2 /15	11	7.99 ± 0.09 [a]	7.04 ± 0.13 [a]	2.30 ± 0.06 [b]	3.04 ± 0.14 [b]
SM					
0.05 /5	63	7.30 ± 0.12 [a]	6.95 ± 0.12 [a]	<1.0± 0.01 [b]	6.77 ± 0.08 [a]

% Preservative/ Temp.	Detected spoilage days	Count (Log_{10} CFU/g)			
		APC	LAB	Ent	Y & M
0.1 /5	77	7.84 ± 0.10 [a]	7.11 ± 0.08 [a]	1.36 ± 0.04 [c]	5.80± 0.10 [b]
0.15 /5			NS		
0.05 /10	11	6.86 ± 0.08 [a]	6.60 ± 0.10 [a]	2.02 ± 0.03 [c]	5.99 ± 0.11 [b]
0.1 /10	49	6.67 ± 0.10 [a]	6.34 ± 0.08 [a]	1.07 ± 0.01 [b]	6.58 ± 0.08 [a]
0.15 /10	56	5.60 ± 0.14 [a]	5.08 ± 0.12 [a]	2.90 ± 0.05 [b]	5.11 ± 0.09 [a]
0.05 /15	9	7.38 ± 0.12 [a]	6.72 ± 0.16 [a]	2.94 ± 0.08 [c]	5.18 ± 0.08 [b]
0.1 /15	25	6.18 ± 0.09 [a]	5.20 ± 0.08 [b]	2.46 ± 0.09 [c]	5.08 ± 0.09 [b]
0.15 /15	32	6.90 ± 0.05 [a]	6.70 ± 0.12 [a]	3.96 ± 0.03 [b]	6.00 ± 0.12 [a]

[*] Mean ± SD.

[**] NS: No sign of spoilage was noticed after 90 days of incubation.

[a-d] Means within the same raw with different letters are significantly ($p \leq 0.05$) different, n = 3.

Table 4. Aerobic plate count (APC) and counts of lactic acid bacteria (LAB), *Enterobacteriaceae* (Ent), both of yeasts and molds (Y & M) at the day of spoilage onset in hummus at different levels of combined sodium benzoate (SB) and sodium metabisulfite (SM) at different storage temperatures.

%SB + SM / Temp.	Detected spoilage days	Count (Log_{10} CFU/g)			
		APC	LAB	Ent	Y & M
0.1 + 0.05 /5	42	7.15 ± 0.08[a*]	6.38 ± 0.13 [a]	1.36 ± 0.07[c]	5.79 ± 0.09 [b]
0.1 + 0.1 /5	84	6.48 ± 0.10 [a]	5.70± 0.08 [b]	<1.0± 0.02 [c]	6.60 ± 0.13 [a]
0.1 + 0.15 /5			NS[**]		
0.15 + 0.05 /5			NS		
0.15 + 0.1 /5			NS		
0.15 + 0.15 /5			NS		
0.1 + 0.05 /10	7	6.30 ± 0.08 [a]	5.36 ± 0.08 [b]	2.01 ±0.01 [c]	5.87 ± 0.12 [ab]
0.1 + 0.1 /10	13	7.9 0± 0.13 [a]	6.36 ± 0.10 [ab]	1.18 ± 0.08 [c]	5.78 ± 0.08 [b]
0.1 + 0.15 /10	25	6.39 ± 0.06 [a]	6.11 ± 0.07 [a]	1.10 ±0.03 [b]	6.03 ± 0.10 [a]
0.15 + 0.05 /10			NS		
0.15 + 0.1 /10			NS		
0.15 + 0.15 /10			NS		

%SB + SM / Temp.	Detected spoilage days	Count (Log_{10} CFU/g)			
		APC	LAB	Ent	Y & M
0.1 + 0.05 /15	7	7.20 ± 0.09 [a]	6.48 ± 0.03 [ab]	1.08 ± 0.01 [c]	5.9 ± 0.08 [b]
0.1 + 0.1 /15	11	6.70 ± 0.14 [a]	6.36 ± 0.12 [b]	2.23 ± 0.03 [c]	5.01 ± 0.09 [b]
0.1 + 0.15 /15	13	7.65 ± 0.10 [a]	6.78 ± 0.09 [ab]	1.08 ± 0.02 [c]	6.70 ± 0.12 [a]
0.15 + 0.05 /15			NS		
0.15 + 0.1 /15			NS		
0.15 + 0.15 /15			NS		

[*] Mean ± SD.

[**] NS: No sign of spoilage was noticed after 90 days of incubation.

[a-d] Means within the same raw with different letters are significantly ($p \leq 0.05$) different, n = 3.

DISCUSSION

Previous work showed that following strict personal hygiene, cleaning and disinfection measures, during the preparation of hummus and proper refrigeration were found effective in controlling microbial proliferation in hummus. When hummus was prepared according to a recipe followed by the University of Jordan Restaurants and under hygienic conditions, aerobic plate and LAB counts were < 10^3 CFU/g, while the coliform and yeast counts were < 10 and 10^3 CFU, respectively (Yamani and Al- Dababseh, 1994). When hummus was collected from the market, higher microbial counts were found compared to that prepared at the University Restaurants. For 61 hummus samples collected from the market, aerobic plate count and the counts of LAB, coliforms and both of yeasts and molds were 2.7×10^7, 1.6×10^7, 2.2×10^3 and 1.5×10^4 CFU/g, respectively. The pH of these samples ranged between 4.2 and 7, and the majority (83%) of the samples had pH > 4.5 (Yamani and Al- Dababseh, 1994). In the present study, lower microbial counts for hummus were recorded, which could be a result of hummus preparation under hygienic conditions and keeping under controlled refrigeration temperature (5 °C) until its use. Acidification of hummus to pH 4.5 may have helped in limiting the growth and multiplication of contaminating microorganisms and extended the shelf life of hummus to 15 days at 5 °C without using preservatives (Table 2). This was a very positive result, since a previous study reported that commercial hummus prepared without preservatives was spoiled within 72 hours under the usual handling conditions.

The use of chemical preservatives is an effective mean to control food spoilage, but this should not be an alternative to good production practices, and lower initial counts of contaminating microorganisms are essential for a better effectiveness of the preservatives (ICMSF, 2005). Both of PS and SB are well-known for their higher effectiveness against yeasts and molds than against bacteria, and the preservative PS has a more inhibitory effect than SB (Castle, 2004). Mihyar et al. (1997) reported that PS and SB at levels of 250 and > 400 mg/kg extended the shelf life of labaneh (concentrated yoghurt) from 14 days to 21 days, respectively, and that both preservatives were very effective against 10 species of spoilage yeasts isolated

from labaneh. Results of the current study agree with these findings in respect to effective inhibition of PS and SB of yeasts and molds compared to bacteria and that PS inhibits tested microorganisms more than SB (Table 3).

Sodium metabisulfite represented the most effective individual treatment in controlling the spoilage of hummus followed by PS and SB (Tables 2 and 3). It is also more effective against *Enterobacteriaceae* than against LAB and both of yeasts and molds (Tables 3 and 4). Sodium metabisulfite is an effective inhibitor against a wide range of microorganisms including gram negative, gram positive and both of yeasts and molds (Arroyo-López et al., 2008; Castle, 2004). The insufficient effectiveness of SM against LAB and both of yeasts and molds in the current study could be explained by the abundance of hummus containment of essential nutrients such as oligosaccharides and B-complex vitamins and the low pH (4.5) condition of hummus favorable for LAB and both of yeasts and molds. The simultaneous addition of SM with PS had an impressive synergistic effect but was less effective when sodium benzoate was combined with SM. Similar results were obtained by Fisher and Golden (1998) who found that combinations of sodium sulfite and sodium benzoate were not more effective than when either of them was used alone in controlling the recovery of *Escherichia coli* O157:H7 in apple cider.

Using hummus at pH values lower than 5.0 could improve the effectiveness of preservatives used. Sodium benzoate, PS and SM have pKa values of 4.20, 4.75 and 7.18, respectively (Mihyar et al., 1997; Scotter and Castle, 2004). The pKa is defined as the pH at which 50 % of the organic acid (preservatives) is in the undissociated form. Lowering the pH value is known to enhance the effect of organic acid preservatives since large proportions of molecules for these preservatives will be present in the undissociated form (Hazan et al., 2004; Scotter and Castle, 2004). Molecules at the undissociated form can easily enter the microbial cells and re-dissociate inside them causing internal acidification and subsequently malfunctioning of the cells (Rahman, 2007). The higher pKa value of SM and PS than the pH of hummus (4.5) means that most of these molecules will be in the undissociated (effective) form, while the lower pKa of the SB below the pH of hummus means that a lower proportion of this compound will be in the undissociated form when present in hummus. This could explain the higher antimicrobial effectiveness of SM and PS compared to SB.

CONCLUSIONS

Addition of PS, SB and SM extended the shelf life of hummus. Sodium metabisulfite was the most effective preservative followed by PS and SB, respectively. LAB were the predominant microorganisms that caused the spoilage of the control as well PS and SB treated hummus during storage at 5 °C. Yeasts and molds had higher contributions as spoilage microorganisms during storage at 5 °C in the control and SB treated hummus than at higher temperatures. Sodium metabisulfite treated hummus was more effective against *Enterobacteriaceae* compared to LAB and both of yeasts and molds. Combined treated hummus with SM and PS increased their effectiveness as compared to combined treated hummus with SM and SB regardless of the temperature level used.

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أثر مواد حافظة كيميائية على مدة صلاحية الحمص في درجات حرارة خزن مختلفة

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ملخـص

تمت إضافة مستويات مختلفة من كل من سوربات البوتاسيوم وبنزوات الصوديوم وميتابيسلفيت الصوديوم على انفراد أو بتوليفات الى الحمص الذي تم تخفيض الرقم الهيدروجيني له إلى 4.5 قبل التخزين في درجات حرارة 5 و 10 و 15°س. وتبين أن إضافة 0.05% و 0.1% من سوربات البوتاسيوم زادت مدة صلاحية الحمص إلى 35 يوماً و 49 يوماً، على التوالي، بينما كانت مدة الصلاحية 15 يوماً للشاهد (حمص من غير مواد حافظة). ولزم 0.1% و 0.15 % من بنزوات الصوديوم للتوصل إلى نفس مدة صلاحية الحمص المعامل بسوربات البوتاسيوم. وكانت ميتابيسلفيت الصوديوم المادة الحافظة الأكثر كفاءة، فإضافة 0.05% و 0.1% كانت مرتبطة بمدة صلاحية بلغت 63 يوماً و 77 يوماً، على التوالي. وزادت توليفات 0.05% من كل من ميتابيسلفيت الصوديوم و سوربات البوتاسيوم، وكذلك ≤0.05 % من ميتابيسلفيت الصوديوم و ≤ 0.15% من بنزوات الصوديوم مدة صلاحية الحمص إلى > 90 يوماً. قلل تخزين الحمص عند 10 و 15°س مدة صلاحيته لكل مستويات المواد الحافظة المستعملة وأنواعها. كانت بكتيريا حمض اللبن السائدة عند بداية الفساد للشاهد وللحمص المعامل بسوربات البوتاسيوم وبنزوات الصوديوم بينما بقيت أعداد البكتيريا المعوية والخمائر والأعفان أقل معنوياً ($p \leq 0.5$) من أعداد بكتيريا حمض اللبن. وكانت بكتيريا حمض اللبن والخمائر والأعفان في كل معاملات ميتابيسلفيت الصوديوم السائدة بينما بقيت البكتيريا المعوية بأعداد أقل معنوياً ($p \leq 0.5$).

الكلمات الدالة: حمص، مدة الصلاحية، سوربات البوتاسيوم، بنزوات الصوديوم، ميتابيسلفيت الصوديوم، مواد حافظة.

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