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Full Length Research Paper

Effect of tomato cultivars, honey finisher and processing methods on quality of tomato ketchup

M. Temesgen[1], T. S. Workneh[2]* and G. Bultossa[1]

[1]Haramaya University, Institute of Technology, Department of Food Science and Postharvest Technology, P O Box 138, Dire Dawa, Ethiopia.
[2]School of Bioresources Engineering and Environmental Hydrology, Faculty of Engineering, University of Kwa-Zulu Natal, Private Bag x0l, Scottsville, 3209, Pietermaritzburg, South Africa.

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The experiment was carried out using factorial combination of two tomato varieties, two processing methods and three honey and one sugar concentrations with three replications. Tomato ketchups prepared from *Melkashola* subjected to pre-heat treatment before cooking exhibited higher total soluble solids, reducing and total sugars, as well as lower microbiological load. However, heat treatment significantly influenced the color of ketchups. Variety and processing methods significantly ($P \leq 0.01$) affected the physico-chemical, microbiological and sensory qualities of the ketchup. Also, honey concentration treatment improved the quality of ketchup. Addition of honey at 500 ml level resulted in higher reducing sugar, total sugar, titratable acidity and total soluble solids content. However, this treatment led to lower moisture content, pH and microbial activity of tomato ketchup. The interaction between variety and processing methods combined with honey concentration treatments were significant at $P \leq 0.01$ level. Similarly, the combined effect of variety, processing method and honey concentration resulted in higher moisture content, pH and reduction in microbial population, while it maintained higher total soluble solid, total sugar, reducing sugar, titratable acidity and ascorbic acid of the ketchups. Ketchups manufactured from fresh juice of *Marglobe* and *Melkashola* had good color. The taste and flavor of ketchups that received high concentration of honey had higher score when compared to the control without honey.

Keywords: Cultivars, honey finisher, fresh juice, blanched juice.

INTRODUCTION

In Ethiopia, high percentage (25 to 30%) of fresh product is lost due to poor handling, inappropriate storage, transportation and lack of proper processing and preservation techniques. Tomato is one of the most commonly cultivated and consumed vegetable fruit in the country. However, higher percentage of this product is lost prior to utilization during harvesting, transportation and short time ambient storage. Hence, there is an urgent need for further study to develop proper procedure to prolong its shelf life and uplift food insecurity in the region. Tomato can be processed into different final functional products such as ketchup, dried tomato, juice and puree. Thus, introduction and promotion of tomato processing aimed at value addition and shelf-life extension through the development shelf stable product could partly solve these problems. This could contribute to the reduction of tomato postharvest losses and also allow income generation, particularly by low income entrepreneurs (Biodiversity International, 2007).

This study was therefore designed to evaluate the suitability of two different tomato varieties for ketchup production and to also evaluate some physico-chemical, microbiological and sensory quality of tomato ketchup that was prepared using low-cost thermal processing method with the addition of honey as one ingredient.

*Corresponding author. E-mail: seyoum@ukzn.co.za. Tel: +27(0)33-2605490. Fax: +27(0)33-2605818.

MATERIALS AND METHODS

Experimental procedure and sample preparation

The experiment was arranged in a factorial design with two varieties (*Melkashola* and *Marglobe*), two processing methods (fresh juice and blanched juice), three honey and sugar concentrations (300, 400 and 500 ml) and 250 g of sugar (control) with three replications. The two varieties of tomatoes of 200 kg were thoroughly washed and divided into two 100 kg each, and then subdivided further into 50 kg subsamples while preparing for the two processing methods (fresh and blanched juice). The ingredients used per 200 kg tomatoes puree were fresh onion (5 kg), white pepper powder (1 kg), black pepper powder (1 kg), sugar (4 kg), mustard powder (1 kg), cinnamon powder (1 kg), cloves powder (1 kg), fresh ground garlic (1 kg), fresh chopped ginger (1 kg) and honey (6 kg). The tomato samples were cut into fine pieces and the green portion was removed (McDermott, 1993). The sliced tomatoes were macerated using juice extractor (6001x model No. 31JE35 6 x 0.00777) for fresh juice initial samples (Yamagucim, 1993). Muslin cloth was used as filter to remove the tomato seeds from the extracted juice. The resulting clear juice was mixed with the ingredients such as onion (2.5 kg L^{-1}), ginger (0.5 kg L^{-1}) and garlic (0.5 kg L^{-1}) in a large pan over heat and was stirred occasionally until very soft product is attained (Gould, 1996). Then, the whole mixture was thoroughly mixed with sugar (1.5 kg L^{-1}) and common salt (1.5 kg L^{-1}). Following this, cinnamon (0.5 kg L^{-1}), cloves (0.5 kg L^{-1}), black pepper (0.5 kg L^{-1}), mustard (0.5 kg L^{-1}) and white peppers (0.5 kg L^{-1}) were tied in muslin and placed into stew.

Finally, the mixture was brought to boil and the cooking continued at 120°C for 2 h. At the end, vinegar (500 ml L^{-1}) was added by allowing it to bubble gently through careful stirring until thoroughly blended and a quite thick paste was made (Yamagucim, 1993). The hot thick paste was equally divided into four and then mixed with sugar (250 g) and honey at 300, 400 and 500 ml levels concentrations. For the second processing method, 50 kg tomato samples from varieties *Melkashola* and *Marglobe* were washed and blanched using hot water at 60°C for 10 min (Cantwell et al., 2001). The blanched tomatoes were allowed to cool and then sliced. The sliced tomatoes were liquidized using juice extractor (6001x model No. 31JE35 6x.00777) and the puree was collected in a clean plastic container.

Physico-chemical quality analysis

The color of tomato ketchup samples were measured by comparing it with standard color chart (Dadzie and Orchard, 1997; Kader, 1992). The consistency of the tomato ketchup sample was measured using ordinary pipette with a volume of 25 ml. The overall consistency determination was expressed as very consistent (4), moderately consistent (3), consistent (2) or less consistent (1) by recording the time at which the samples were poured through the pipette (Dadzie and Orchard, 1997). Ketchup sample (30 g) was placed in a container and their weight was recorded. Then, the samples were placed in hot air drying oven for moisture content determination at 105°C for 2 h (Minton, 1996; Dadzie and Orched, 1997).

Chemical analysis

The total soluble solid (TSS) was determined following the procedures as described by Waskar et al. (1999). Aliquot of ketchup samples were taken from each jar into 40 ml beakers and using liquid dropper, the ketchup samples ware placed in cleaned muslin cloth to make clear juice TSS recording. The TSS was determined by Abbe refractometer (BS 60/70 Model No. A-90067, Bellingham & Stanley Ltd, England) with a range of 0 to 32 ^{0}Brix, and a resolution of 0.2 ^{0}Brix by placing 1 to 2 drops of ketchup on the prism. Between samples, the prism of the refractometer was washed with distilled water and dried by a soft paper before use. The refractometer was standardized against distilled water (0% TSS).

Reducing sugar was estimated using the colorimetric method (Somogyi, 1945). 10 ml aliquots were taken from each jar and were added to 15 ml of 80% ethanol and thoroughly mixed. The mixture was heated in the boiling water bath for 30 min, after which the content was cooled under running tap water without shaking. The cooled sample was mixed with 1.5 ml disodium arsenate and 1 ml lead acetate and filtered using filter paper. Then, the extract was made up to 50 ml using a 50 ml volumetric flask, from which 1 ml aliquot was taken and added to test tube. Arsenomolybdate (1 ml) color reagent was added and mixed with the aliquot, then the volume was made up to 10 ml using distilled water and finally left for about 10 min to allow color development, after which the absorbance was determined by a spectrophotometer at 620 nm. For total sugar determination, the extracted sugar was first hydrolyzed with 1 M HCl by heating at 70°C for 30 min. After hydrolysis, the determination of total sugar was made by following the same procedure that was employed for the determination of the reducing sugar in this study.

Furthermore, an aliquot of ketchup was taken and its pH value was measured by glass electrode that was attached to pH meter (model Jenway 3320) at a temperature of 20°C. The titratable acidity (TA) of tomato ketchup was measured as described by Maul et al. (2000). The titratable acidity expressed as percent citric acid was obtained by titrating 10 ml of tomato ketchup with standard NaOH (about 0.1 N) to the end point (persisting for 15 s). The titratable acidity was then expressed as percent citric acid. On the other hand, the ascorbic acid content of tomato ketchup was determined using 2, 6-dichlorophenol indophenol method (AOAC, 1970). A 10-ml aliquot of tomato ketchup was diluted to 50 ml with 3 percent metaphosphoric acid in a 50 ml volumetric flask. The mixture was titrated with the standard dye to the end point (persisting for 15 s). The ascorbic acid content was calculated from the titration value, dye factor and volume of the sample.

Microbiological assay

The total microbial population was estimated using the procedure that had been followed by Bracket (1990). Tomato ketchup samples were taken aseptically from each replication using pre-sterilized pipette and immediately subjected to serial dilution. Sample (1 ml) was serially diluted in 9 ml of 0.1% peptone water that was kept in the refrigerator. The serial dilution was done in the range of 10^{-1} to 10^{-5} series of test tubes. For the estimation of total aerobic bacteria, the sample of 1 ml was taken from the test tube aseptically using discrete pipette and was plated on plate count agar (Bracket, 1990). Finally, all plates were incubated at 30°C for 2 days. The growth in bacteria was inspected after 2 days and the colonies were counted using standard colony counter.

For the estimation of total coliform population, the sample of 1 ml was aseptically taken from the test tube using sterilized discrete pipette and was plated on duplicate violate red bile agar (VRBA) (Harrigan, 1998). Finally, they were placed inverted and incubated at 37°C for 1 day. Afterward, the growth of coli forms was inspected and the colonies were counted using standard colony counter. For the estimation of fungi, the sample of 1 ml was aseptically taken from the test tube using sterilized discrete pipette and was plated on Rose-Bengal chloramphenicol agar base (oxoid CM549) (Harrigan,1998). Then, they were placed inverted and incubated at 25°C for 3 to 5 days. The growth in yeast was inspected after 3 days and non growth plates were incubated for two days more to complete the recommended incubation period.

Table 1. Colour type and consistency level of processed tomato ketchup as evaluated by the standard colour chart and consistency measurement.

Treatment	Ingredients' concentrations	Colour type	Consistency reference level
Marglobe			
Fresh juice	250 g sugar	Deep red	1
	300 ml honey	Deep red	2
	400 ml honey	Deep red	2
	500 ml honey	Deep red	2
Blanched juice	250 g sugar	Bright red	2
	300 ml honey	Bright red	3
	400 ml honey	Bright red	3
	500 ml honey	Yellow red	4
Melkashola			
Fresh juice	250 g sugar	Deep red	1
	300 ml honey	Deep red	2
	400 ml honey	Deep red	3
	500 ml honey	Yellow red	3
Blanched juice	250 g sugar	Deep red	2
	300 ml honey	Yellow red	3
	400 ml honey	Bright red	4
	500 ml honey	Yellow red	4

1, 2, 3 and 4 indicate less consistent, consistent, moderately consistent and very consistent respectively.

Sensory evaluation

Descriptive sensory evaluation was used in the screening of tomato ketchup based on their sensory quality characteristics. A total of 50 panelists were involved in the sensory evaluation. Sixteen duplicates of processed tomato ketchup samples were presented with potato chips for panelists to evaluate the taste, color, flavor and overall acceptability of the samples. During the evaluation period, the panelists attended two sessions. Eight samples were served at each session and then all panelists were allowed to taste and evaluate the samples for each quality feature using rating scale. All panelists were instructed to make their own individual assessments according to the evaluation criteria provided for each samples on the basis of taste, color, flavor and overall acceptability. Finally, the scores of all judges were added and divided by the number of judges to find the final mean score.

Statistical analysis

A factorial combination of the two varieties, two processing methods and four ingredient concentrations treatment with three replications was used in the study. The difference between the treatments was determined by the analysis of variance for factorial experiment using SAS and the comparison of the mean was done by Duncan's multiple rage tests.

RESULTS AND DISCUSSION

Color, consistency and moisture content

The color of the tomato ketchup was found to be either deep red, bright red or yellow red (Table 1). The color of the ketchup was found to be enjoyable when the product was processed from fresh juice as a raw material. This could be attributed to the presence of high concentration of the red pigments called lycopene, xanthophyll and carotene compounds (Abushita et al., 1997). On the other hand, the tomato ketchups that was manufactured from *Marglobe* tomato variety and processed from fresh juice had the deepest red color. Contrary to this, the ketchups prepared from both varieties that were subjected to blanching treatment showed low degree of redness and became brighter colored. This might be due to early pre-processing thermal effect on the biochemical color compounds of the products (Gullet et al., 1994).

The ketchup from *Melkashola* tomato variety had more consistency than the ketchups that were prepared from *Marglobe* tomato variety. This could be attributed to the fact that *Melkashola* contained higher TSS than *Marglobe*. The consistency of ketchups that were processed from tomatoes subjected to blanching was found to be higher than the ketchup samples that were processed from fresh tomato juice. During heating and cooking, the ingredient concentration increases and finally results in high solid contents (Ramesh, 1999). This could be partly also due to heat treatment during blanching of tomatoes that could cause the breakdown of tissue and result in high soluble solids in the product (Lewis, 1990). In addition, ketchups with honey treatment combined with heating resulted in more consistent property than ketchup

Table 2. The interaction effect of variety, processing method and honey concentration on the moisture content (%) of tomato ketchup during 30 days of storage.

Treatment	Ingredient	Storage period (day)			
		1	10	20	30
Marglobe					
Fresh juice	250 g sugar	71[a]	72[a]	72[a]	74[a]
	300 ml honey	68[b]	69[b]	68[c]	70[b]
	400 ml honey	65[d]	65[d]	66[d]	67[c]
	500 ml honey	61[f]	61[e]	62[e]	61[f]
Blanched juice	250 g sugar	70[a]	70[b]	72[a]	71[b]
	300 ml honey	66[c]	67[c]	66[d]	67[c]
	400 ml honey	65[d]	65[d]	66[d]	65[d]
	500 ml honey	62[e]	62[e]	62[e]	63[e]
Melkashola					
Fresh juice	250 g sugar	69[b]	69[b]	70[b]	71[b]
	300 ml honey	68[b]	69[b]	68[c]	70[b]
	400 ml honey	66[c]	67[c]	66[d]	67[c]
	500 ml honey	61[f]	60[f]	60[f]	61[f]
Blanched juice	250 g sugar	56[g]	55[g]	55[g]	56[g]
	300 ml honey	55[h]	55[g]	54[g]	56[g]
	400 ml honey	53[i]	53[h]	51[h]	51[h]
	500 ml honey	49[j]	51[i]	50[i]	50[i]
Significance	CV (%)	5.00	4.84	4.06	2.25
	SE±	1.78		1.47	0.84

** indicate significant difference at 0.01. Means within a column followed by the same letter (s) are not significantly different at $P < 0.05$. A, variety; B, processing method; C, ingredient's concentration.

prepared from samples that was subjected to the other treatments.

In addition, the moisture content of the tomato ketchup samples varied between 49 and 74% (Table 2), which were in agreement with the previous report by Barbosa-Canovas (1996) who showed that the moisture content of tomato ketchup varies between 45 and 80%. The difference among variety, processing methods and honey concentration treatments was highly significant ($P \leq 0.01$) on the moisture content of the tomato ketchup samples. The moisture content of ketchups prepared from fresh juice of *Marglobe* variety were found to be the highest, while the lowest moisture contents were recorded for the ketchup samples that were manufactured from blanched juice of *Melkashola* variety. Furthermore, there was a significant ($P \leq 0.05$) reduction in the moisture content of tomato ketchups that was subjected to high honey concentration (500 ml) compared with tomato ketchups without honey treatment. In addition, there was a significant ($P \leq 0.05$) difference in the moisture contents of the tomato ketchup samples that were processed from fresh juice and blanched juice method. The general trend of lower moisture content was observed in tomato ketchup samples that were prepared from *Melkashola* than from *Marglobe*. It is well known that processing with heat increases consistency and decreases moisture content due to the loss of water resulting from evaporation of water.

Chemical quality

The TSS content of tomato ketchup samples ranged between 21.3 and 30.3 ^{0}Brix (Table 3), which was in agreement with the previous findings by Minton (1996) who reported TSS content varying from 19 to 35 ^{0}Brix in the ketchup samples that were prepared using different combination of salt and sugar quantities. The TSS content of ketchup include sugars, organic acids, soluble pectin's, spices, phytochemicals and mineral salts (Minton, 1996). Among the TSS constituents, sugars and organic acids comprise the majority of the total dry matter content of ketchup, while the remainder is made of mineral salts, flavonoids, polyphenols and other phytochemicals (Minton, 1996). The TSS content of tomato ketchup samples

Table 3. The interaction effect of variety, processing method and honey concentration on the total soluble solid (TSS °Brix) content of tomato ketchup during 30 days of storage.

Treatment	Ingredients' concentrations	Storage period (day)			
		1	10	20	30
Marglobe					
Fresh juice	250 g sugar	23.33^{g}	23.33^{f}	24.33^{e}	24.66^{d}
	300 ml honey	21.33^{h}	21.66^{g}	23.66^{e}	23.33^{e}
	400 ml honey	23.33^{g}	25.00^{d}	25.00^{d}	24.33^{d}
	500 ml honey	25.00^{e}	25.00^{d}	26.33^{c}	26.66^{c}
Blanched juice	250 g sugar	24.00^{f}	24.33^{e}	24.33^{e}	24.33^{d}
	300 ml honey	23.33^{g}	23.33^{f}	23.33^{f}	25.00^{d}
	400 ml honey	24.66^{f}	26.33^{c}	26.66^{c}	26.33^{c}
	500 ml honey	25.66^{e}	26.33^{c}	26.66^{c}	26.66^{c}
Melkashola					
Fresh juice	250 g sugar	26.66^{d}	25.33^{d}	25.33^{d}	26.33^{c}
	300 ml honey	26.00^{d}	26.33^{c}	26.33^{c}	26.00^{c}
	400 ml honey	27.00^{c}	27.33^{b}	27.66^{b}	26.66^{c}
	500 ml honey	28.00^{b}	28.00^{a}	27.00^{b}	28.66^{b}
Blanched juice	250 g sugar	25.66^{e}	26.33^{c}	26.66^{c}	26.00^{c}
	300 ml honey	27.66^{c}	28.66a	29.00^{a}	29.66^{a}
	400 ml honey	27.66^{c}	28.00^{a}	29.00^{a}	28.00^{b}
	500 ml honey	29.00^{a}	28.33^{a}	29.00^{a}	30.33^{a}
Significance level	CV (%)	3.70	6.02	2.05	2.76
	SE±	0.54	0.89	0.31	0.43
	A × B ×C	**	**	**	**

**Indicate significantly different at 0.01. Means within a column followed by the same letter (s) are not significantly different at $P < 0.05$. A, Variety; B, processing method; C, ingredient's concentration.

manufactured from blanched juice of *Melkashola* were found to be the highest, while the lowest TSS content were obtained in ketchup samples that were manufactured from fresh juice of *Marglobe* variety. On the other hand, the highest (30.3 ^{0}Brix) TSS content was obtained in *Melkashola* variety subjected to blanching treatment. The ketchups made from fresh *Marglobe* juice contained the lowest TSS content of 21.3 ^{0}Brix. The TSS content of ketchups prepared from fresh juice of *Melkashola* were found to be higher than the TSS content of ketchups that were prepared from blanched juice of *Marglobe* variety.

The addition of honey during ketchup processing as a finisher and preservative provided consistent and long life preserved product in addition to its sweetening and nutrition effect (Wood, 1998). When honey is added to ketchup, it increases the TSS, sugars, flavors, antimicrobial and anti-oxidant substances, which are known to improve the physical and chemical quality of ketchup (Martinez and Jimenez, 2003). The addition of common salt during processing dissolves some of the pectin and thereby results in the increase of TSS (Campbell, 1995). Therefore, the increase in honey concentrations also results in high TSS content and the overall TSS content increased with the addition of ingredients in this study.

The reducing and total sugar contents of ketchups ranged between 1.7 and 2.9% and 2.4 and 7.6%, respectively (Tables 4 and 5). The difference among variety, processing methods and honey concentration treatments were highly significant ($P \leq 0.01$). The reducing and total sugar content of ketchups prepared from blanched juice of *Melkashola* variety were found to be the highest, while the lowest reducing and total sugar content of ketchups were obtained from ketchup manufactured from fresh juice of *Marglobe* variety. The reducing sugar content of ketchups prepared from fresh juice of *Melkashola* variety were higher than that of ketchups prepared from blanched juice of *Marglobe* variety. The concentrations of reducing and total sugar (2.9 and7.6%) were found in *Melkashola* variety that was subjected to blanching combined with the addition of high honey treatment. The lowest (1.8 and 2.4%) reducing and total sugar concentrations were recorded in ketchup samples of *Marglobe*

Table 4. The interaction effect of variety, processing method and honey concentration on the reducing sugar (g 100 g^{-1}) content of tomato ketchup during 30 days of storage.

Treatment	Ingredient concentration	Storage period (day)			
		1	10	20	30
Marglobe					
Fresh juice	250 g sugar	1.77^{g}	1.76^{g}	1.76^{g}	1.74^{h}
	300 ml honey	1.80^{g}	1.81^{g}	1.81^{g}	1.82^{g}
	400 ml honey	1.88^{f}	1.88^{f}	1.88^{f}	1.89^{f}
	500 ml honey	1.91^{f}	1.93^{f}	1.92^{f}	1.92^{f}
Blanched juice	250 g sugar	1.93^{f}	1.91^{f}	1.93^{f}	1.93^{f}
	300 ml honey	2.23^{e}	2.22^{e}	2.23^{e}	2.22^{e}
	400 ml honey	2.34^{d}	2.35^{d}	2.34^{d}	2.34^{d}
	500 ml honey	2.56^{c}	2.55^{c}	2.55^{c}	2.57^{c}
Melkashola					
Fresh juice	250 g sugar	2.57^{c}	2.56^{c}	2.56^{c}	2.57^{c}
	300 ml honey	2.57^{c}	2.56^{c}	2.57^{c}	2.58^{c}
	400 ml honey	2.58^{c}	2.59^{c}	2.59^{c}	2.58^{c}
	500 ml honey	2.62^{c}	2.60^{c}	2.60^{c}	2.63^{c}
Blanched juice	250 g sugar	2.75^{b}	2.75^{b}	2.75^{b}	2.76^{b}
	300 ml honey	2.78^{b}	2.78^{b}	2.79^{b}	2.78^{b}
	400 ml honey	2.83^{b}	2.83^{b}	2.83^{b}	2.84^{b}
	500 ml honey	2.91^{a}	2.92^{a}	2.93^{a}	2.92^{a}
Significance level	CV (%)	7.02	9.81	5.17	4.46
	SE±	0.09	0.11	0.60	0.05
	A × B × C	**	**	**	**

**Indicate significantly different at 0.01. Means within a column followed by the same letter (s) are not significantly different at $p < 0.05$. A, Variety; B, processing method; C, ingredient's concentration.

Table 5. The interaction effect of variety, processing methods and honey concentration on the total sugar (g100g^{-1}) content of tomato ketchup during 30 days of storage.

Treatment	Ingredient concentration	Storage period (day)			
		1	10	20	30
Marglobe					
Fresh juice	250 g sugar	2.44^{i}	2.44^{i}	2.43^{i}	2.43^{i}
	300 ml honey	2.48^{i}	2.47^{i}	2.47^{i}	2.47^{i}
	400 ml honey	2.49^{i}	2.48^{i}	2.48^{i}	2.48^{i}
	500 ml honey	2.55^{h}	2.55^{h}	2.55^{h}	2.54^{h}
Blanched juice	250 g sugar	2.62^{g}	2.63^{g}	2.62^{g}	2.62^{g}
	300 ml honey	3.43^{f}	3.43^{f}	3.44^{f}	3.43^{f}
	400 ml honey	3.93^{e}	3.93^{e}	3.93^{e}	3.94^{e}
	500 ml honey	4.23^{e}	4.23^{e}	4.24^{e}	4.23^{e}
Melkashola					
Fresh juice	250 g sugar	5.16^{d}	5.16^{d}	5.16^{d}	5.17^{d}
	300 ml honey	5.26^{d}	5.26^{d}	5.26^{d}	5.27^{d}
	400 ml honey	5.51^{d}	5.51^{d}	5.51^{d}	5.50^{d}

Table 5. Contiune

	500 ml honey	6.42[c]	6.43[c]	6.42[c]	6.42[c]
	250 g sugar	6.61[c]	6.61[c]	6.62[c]	6.63[c]
Blanched juice	300 ml honey	6.72[c]	6.73[c]	6.73[c]	6.73[c]
	400 ml honey	7.22[b]	7.22[b]	7.23[b]	7.22[b]
	500 ml honey	7.66[a]	7.66[a]	7.65[a]	7.66[a]
	SE+	7.21	8.32	9.01	5.80
Significance level	CV (%)	0.20	0.53	0.28	0.22
	A × B × C	**	**	**	**

**Indicate significantly different at 0.01. Means within a column followed by the same letter (s) are not significantly different at $P < 0.05$. A, Variety; B, processing method; C, ingredient's concentration.

variety that were subjected to fresh juice processing without honey treatment. This could be associated with the increase in reducing and total sugar contents, which could possibly be due to high TSS content in ketchups made from *Melkashola* variety when subjected to pre-cooking blanching treatment with the addition of honey than the others treatments. Similar results were also reported by Baldwin et al. (1991). Ketchups processed by heating of tomatoes before cooking could increase the reducing and total sugars due to the break down of carbohydrates into their reducing sugars forms.

The reducing and total sugars in the ketchup are contributed by glucose, fructose and galactose from tomato, honey and spices. It was shown that tomato variety with high reducing and total sugars resulted in ketchups with high reducing and total sugars. The increase in reducing and total sugars could be due to higher reducing and total sugars in the tomato varieties and partly due to the addition of honey, which is in a positive agreement with the findings of Baldwin et al. (1991). The increase in reducing and total sugars could also be associated with the breakdown of polysaccharides into reducing sugars when subjected to high temperature cooking. Temperature had heavily influenced the breakdown of polysaccharides into their reducing forms. These reactions ordinarily increase with an increase in cooking temperature during the thermal processing of ketchups.

As the finding of the study revealed, the pH of tomato ketchup was acidic and ranges from 3.52 to 3.95 (Table 6), which was in agreement with the result of Saliba-Colombani et al. (2001). The difference in pH value of tomato ketchup samples among varieties, processing methods and honey concentration treatments was highly significant ($P \leq 0.0$). The pH values of ketchups manufactured from blanched juice of *Marglobe* were found to be the highest, while the lowest pH value in the ketchup samples were obtained from blanched juice of *Melkashola* variety. The pH values of ketchups prepared from fresh juice of *Marglobe* treated with 400 and 500 ml of honey were found to be greater than that of ketchups prepared from fresh juice of *Melkashola* variety. Furthermore, the pH value decreased with increasing honey concentration. This could be due to the pH difference experienced between the varieties, and the presence of organic acids in honey could also partly contribute to lower pH value of the ketchup (Saliba-Colombani et al., 2001).

Processing methods also had significant ($P \leq 0.05$) effect on pH value in the cases of both varieties. This might be due to the minimum heat treatment on the tomatoes before cooking that had no great change in pH value. This could also be attributed to losses of acids during processing at high temperature. In general, the pH value varies depending on the genetic factors such as variety and honey concentrations treatments. Such variations are attributed to the concentration of honey than to the genetic differences resulting from varietal differences. In addition, the variability in pH value that has been observed within different combinations of treatments could be partly due to the initial pH value of the raw materials and the length of cooking time after the vinegar was added. The TA percent difference among variety, processing method and honey concentration treatments was also highly significant ($P \leq 0.01$) (Table 7). The titratable acid content of ketchups manufactured from fresh juice of *Melkashola* variety were the highest, while the lowest titratable acid content in ketchups were obtained from blanched juice of *Marglobe* variety. The titratable acidity of ketchups manufactured from fresh juice of *Marglobe* variety were greater than that of ketchups manufactured from blanched juice of *Melkashola* variety.

Variety, processing methods and honey concentration treatments had significant ($P \leq 0.01$) influence on the ascorbic acid (AA) content (Table 8). The ascorbic acid content of ketchups prepared from fresh juice of *Melkashola* variety were found to be the highest, while the lowest ascorbic acid content was found in samples prepared from the blanched juice samples of *Marglobe* variety. The ascorbic acid contents of ketchups that were manufactured from fresh juice of *Marglobe* were found to be greater than that of ketchups manufactured from blanched juice of *Melkashola* variety. Tomato ketchups prepared from fresh juice of *Melkashola* variety had the highest

Table 6. The interaction effect of variety, processing method and honey concentration on the pH value of tomato ketchup during 30 days of storage.

Treatment	Ingredient	Storage period (day)			
		1	10	20	30
Marglobe					
Fresh juice	250 g sugar	3.86^{b}	3.86^{b}	3.86^{b}	3.86^{b}
	300 ml honey	3.73^{c}	3.73^{c}	3.73^{c}	3.72^{c}
	400 ml honey	3.70^{c}	3.71^{c}	3.70^{c}	3.70^{c}
	500 ml honey	3.69^{c}	3.69^{c}	3.69^{c}	3.69^{c}
Blanched juice	250 g sugar	3.95^{a}	3.94^{a}	3.94^{a}	3.94^{a}
	300 ml honey	3.95^{a}	3.94^{a}	3.94^{a}	3.94^{a}
	400 ml honey	3.91^{a}	3.91^{a}	3.91^{a}	3.91^{a}
	500 ml honey	3.86^{b}	3.86^{b}	3.86^{b}	3.86^{b}
Melkashola					
Fresh juice	250 g sugar	3.93^{a}	3.93^{a}	3.93^{a}	3.94^{a}
	300 ml honey	3.81^{b}	3.81^{b}	3.82^{b}	3.82^{b}
	400 ml honey	3.64^{d}	3.64^{d}	3.64^{d}	3.64^{d}
	500 ml honey	3.60^{d}	3.60^{d}	3.61^{d}	3.60^{d}
Blanched juice	250 g sugar	3.86^{b}	3.86^{b}	3.86^{b}	3.86^{b}
	300 ml honey	3.53^{e}	3.54^{e}	3.54^{e}	3.54^{e}
	400 ml honey	3.53e	3.53^{e}	3.52^{e}	3.52^{e}
	500 ml honey	3.63^{d}	3.63^{d}	3.66^{d}	3.66^{d}
Significance level	CV (%)	1.68	1.45	2.22	1.66
	SE±	0.036	0.02	0.04	0.03
	A × B × C	**	**	**	**

**Indicate significantly different at 0.01. Means within a column followed by the same letter (s) are not significantly different at $P < 0.05$. A, Variety; B, processing method; C, ingredient's concentration.

Table 7. The interaction effect of variety, processing method and honey concentration on the titratable acid (ta) (%) content of tomato ketchup during 30 days of storage.

Varieties/ processing methods	Ingredient's concentration	Storage period (day)			
		1	10	20	30
Marglobe					
Fresh juice	250 g sugar	0.37^{c}	0.37^{c}	0.37^{c}	0.38^{c}
	300 ml honey	0.43^{b}	0.43^{b}	0.43^{b}	0.43^{c}
	400 ml honey	0.44^{b}	0.45^{b}	0.45^{b}	0.45^{b}
	500 ml honey	0.48^{b}	0.48^{b}	0.48^{b}	0.48^{b}
Blanched juice	250 g sugar	0.24^{e}	0.23^{d}	0.24^{e}	0.24^{e}
	300 ml honey	0.29^{d}	0.30^{c}	0.29^{d}	0.29^{e}
	400 ml honey	0.34^{c}	0.34^{c}	0.34^{c}	0.34^{d}
	500 ml honey	0.44^{b}	0.44^{b}	0.45^{b}	0.44^{b}
Melkashola					
Fresh juice	250 g sugar	0.45^{b}	0.45^{b}	0.45^{b}	0.45^{b}
	300 ml honey	0.54^{a}	0.55^{a}	0.52^{a}	0.52^{a}
	400 ml honey	0.56^{a}	0.56^{a}	0.55^{a}	0.56^{a}

Table 7. Contiune

	500 ml honey	0.58[a]	0.58[a]	0.58[a]	0.57[a]
Blanched juice	250 g sugar	0.35[c]	0.35[c]	0.35[c]	0.34[c]
	300 ml honey	0.38[c]	0.38[c]	0.38[c]	0.38[c]
	400 ml honey	0.44[b]	0.44[b]	0.44[b]	0.44[b]
	500 ml honey	0.45[b]	0.45[b]	0.45[b]	0.44[b]
	CV (%)	5.37	6.01	8.65	4.31
	SE±	0.0013	0.0014	0.001	0.0011
Significance level	A × B × C	**	**	**	**

**Indicate significantly different at 0.01. Means within a column followed by the same letter (s) are not significantly different at $P < 0.05$ according to DMRT. A, Variety; B, processing method; C, ingredient's concentration.

Table 8. The interaction effect of variety, processing method and honey concentration on the ascorbic acid content (mg /100 g) of tomato ketchup during 30 days of storage.

Treatment	Ingredient's concentration	Storage period (day)			
		1	10	20	30
Marglobe					
Fresh juice	250 g sugar	9.87[c]	9.87[c]	9.87[c]	9.87[c]
	300 ml honey	9.93[b]	9.94[b]	9.94[b]	9.94[b]
	400 ml honey	9.95[b]	9.96[b]	9.96[b]	9.96[b]
	500 ml honey	9.99[a]	9.99[a]	9.99[a]	9.99[a]
Blanched juice	250 g sugar	9.83[c]	9.83[c]	9.83[c]	9.83[c]
	300 ml honey	9.87[c]	9.87[c]	9.87[c]	9.87[c]
	400 ml honey	9.87[c]	9.87[c]	9.87[c]	9.87[c]
	500 ml honey	9.93[b]	9.93[b]	9.93[b]	9.93[b]
Melkashola					
Fresh juice	250 g sugar	9.95[b]	9. 95[b]	9.95[b]	9.95[b]
	300 ml honey	9.95[b]	9.96[b]	9.95[b]	9.95[b]
	400 ml honey	9.95[b]	9.95[b]	9.95[b]	9.95[b]
	500 ml honey	10.00[a]	10.00[a]	10.00[a]	10.00[a]
Blanched juice	250 g sugar	9.93[b]	9.93[b]	9.93[b]	9.93[b]
	300 ml honey	9.95[b]	9.95[b]	9.95[b]	9.95[b]
	400 ml honey	9.95[b]	9.95[b]	9.95[b]	9.95[b]
	500 ml honey	9.96[b]	9.96[b]	9.96[b]	9.97[b]
	CV (%)	0.75	0.51	0.55	0.55
Significance level	SE±	0.042	0.02	0.03	0.03
	A × B × C	**	**	**	**

**Indicate significantly different at 0.01. Means within a column followed by the same letter (s) are not significantly different at $P < 0.05$. A, variety; B, processing method; C, ingredient's concentration.

ascorbic acid content, while the lowest ascorbic acid concentrations were found in tomato ketchup manufactured from blanched juice of *Marglobe* variety. This could be due to the initial ascorbic acid content of the variety and the application of heat treatment could affect the availability of ascorbic acid. This result indicated that the difference in acid contents have relation with the type of product processed (Kader, 2002). Tomato ketchups treated with honey showed an increase in ascorbic acid content than that of ketchups subjected to sugar treatment. The addition of honey at high concentration level also increased the ascorbic acid contents of the ketchup samples. This could be also due to the presence of ascorbic acid (vitamin C) in honey (Martinez et al., 2003).

Microbiological population

Variety, processing methods and honey concentration treatments were not significant ($P > 0.05$) on the total aerobic bacteria, total coli form and yeast population (data not shown). There was no microbial growth

Table 9. Percentage of judges from sensory qualities of tomato ketchup.

Characteristics and attributes	Sensory quality		
	Grading percentage (%)		
	Low	Medium	High
Sweetness	4	10	16
Saltiness	14	16	26
Sourness	2	4	10
Astringent	-	-	-
Colour	Deep red; 48	Bright red; 16	Yellow red; 36
Flavor	Less flavor; 6	Medium flavor; 52	High flavor; 42
Overall acceptability	Less acceptable; 22	Moderately acceptable; 52	Highly acceptable; 26

throughout the storage periods. This could be due to the fact that cooking temperature and preservatives appeared to have markedly destroyed the bacteria, coliform and yeasts in the samples. Cooking temperature was one of the most important factors that controlled the growth of microorganisms. This indicated that all tomato ketchup samples received the heat treatment that was sufficient to kill microbial vegetative cells. Additionally, the additives used, such as salt, sugar, spices, vinegar and honey, could have a negative effect on the microbial in the sample. The substances that are generally added to ketchup such as vinegar, sugar, salt and spices, make the product highly acidic in nature. And due to the acidic nature and the presence of oil in the spices, the growth of microorganisms in the ketchup is fully inhibited (Borch et al., 1998). Also, the addition of salt and sugar lowers the moisture content and reduces water available for microbial growth, which results in low water activity of the food and leads to decreased microbial growth. Furthermore, the addition of acid (vinegar) could denature microbial protein and preserves the ketchups for the required period of storage (Borch et al., 1998). The combination of acids and cooking temperature therefore provides more effective preservative effect.

Moreover, the addition of honey during ketchup processing as a finisher and preservative provides consistency and long life preserved product in addition to its sweetening and improving nutrient effect (Wood, 1998). When honey is added to ketch up, it increases the total soluble solids, sugars, flavors, anti-microbial and anti-oxidant substances, which in turn improve the physical and chemical quality of ketchup. Honey has antimicrobial substances and antioxidants, including chrysin, vitamin C and catalase (Martinez et al., 2003). The other reason for the absence of growth of microorganisms was attributed to aseptic packaging in pre-sterilized jars after processing in order to prevent post-processing contamination and spoilage.

Sensory evaluation

The data show that there was a relationship between the ketchup quality parameters and sensory evaluator response (Tables 9 and 10). The tomato ketchups had good flavor characteristics and fairly red color when processed without tomato peel and seeds. Tomato ketchups manufactured from fresh juice of *Melkashola* and *Marglobe* varieties had fairly red color than that of blanched juice of *Melkashola* and *Marglobe* ketchups. This might be due to the blanching treatment that could have effect on the color and hence result in yellow or bright color profile of the tomato ketchups made from blanched juice of varieties. It is well known that heat treatment slightly break down the red pigment in tomato and cause loss in primary color.

Concerning the saltiness, tomato ketchups manufactured from *Melkashola* that was subjected to pre-heat treatment before cooking had the highest score than the others. This could be due to pre-heat treatment that resulted in loss in moisture and increased solid concentrations. This loss in moisture and increase in solid concentrations could also increase the saltiness of ketchups manufactured from blanched juice of *Melkashola* variety. Tomato ketchups that were manufactured from fresh juice of *Melkashola* variety showed the higher sourness taste than the others. This could be attributed to titratable acid and the absence of pre-heating treatment, which is known to maintain the total acid content. On the other hand, acidity of tomato ketchups reduced with increased heating. The higher acidity in tomato ketchups made from fresh juice of *Melkashola* variety had resulted in the higher sourness taste.

Conclusion

Melkashola variety was found to be superior in terms of the physico-chemical qualities. Pre-heat treatment improved the microbial and chemical constituents of the tomato ketchups. The application of heat treatment is therefore recommended for good microbial and nutritional qualities of ketchups. However, it is not recommended to use high cooking temperature for longer time. The physical, chemical, microbiological and sensory quality of ketchup was

Table 10. The interaction effect of variety, processing methods and honey concentration treatments on the sensory qualities of tomato ketchup.

Treatment	Ingredient concentration	Sensory quality					
		Flavour	Colour	Sweetness	Saltiness	Sourness	Overall acceptance
Marglobe							
Fresh juice	250 g sugar	3.38^{ef}	2.12^{abc}	2.14^{fgh}	2.26^{a}	2.51^{de}	2.11^{ab}
	300 ml honey	3.80^{efg}	1.92^{a}	2.22^{ef}	2.18^{edf}	2.36^{fg}	2.02^{cb}
	400 ml honey	4.42^{def}	2.03^{de}	2.33^{de}	2.21^{bc}	2.54^{cd}	1.96^{d}
	500 ml honey	5.20^{abc}	1.84^{fgh}	2.40^{abc}	2.18^{edf}	2.50^{e}	1.97^{cde}
Blanched juice	250 g sugar	3.46^{de}	2.08^{def}	2.18^{fg}	2.25^{ab}	2.52^{cde}	2.02^{bc}
	300 ml honey	3.82^{defg}	1.75^{gh}	2.22^{efg}	2.18^{cde}	2.42^{f}	2.02^{bc}
	400 ml honey	4.84^{efgh}	2.98^{abc}	2.38^{cde}	2.21^{bc}	2.64^{b}	1.96^{de}
	500 ml honey	5.80^{ab}	1.88^{fg}	2.42^{ab}	2.16^{de}	2.50^{e}	1.96de
Melkashola							
Fresh juice	250 g sugar	3.42^{def}	1.83^{fgh}	2.16^{fgh}	2.26^{a}	2.51^{de}	1.96^{de}
	300 ml honey	4.20^{abc}	2.01^{cde}	2.22^{efg}	2.21^{bcd}	2.38^{g}	1.98^{cd}
	400 ml honey	4.62^{cde}	1.84^{fgh}	2.42^{ab}	2.22^{b}	2.58^{bc}	2.01^{cd}
	500 ml honey	5.40^{abcd}	2.10^{cde}	2.41^{ab}	2.18^{cde}	2.51^{de}	2.04^{b}
Blanched juice	250 g sugar	3.54^{def}	1.86^{fgh}	2.18^{fg}	2.20^{cd}	5.52^{a}	1.96^{d}
	300 ml honey	3.86^{efg}	2.06^{de}	2.25^{def}	2.20^{cd}	2.58^{ef}	1.98^{cd}
	400 ml honey	5.16^{a}	2.08^{defg}	2.35^{cd}	2.22^{b}	2.66^{b}	2.14^{a}
	500 ml honey	5.84^{efg}	2.12^{abc}	2.38^{cde}	2.26^{a}	2.68^{ef}	2.21^{c}
CV (%)		3.427	2.029	2.43	2.21	2.69	2.011

Means within a column followed by the same letter (s) are not significantly different ($P < 0.05$) based on the following evaluation scale. For sweetness, saltiness, bitterness and sourness: 1, very; 2, moderately and 3, less. For flavour: 1, very low; 2, low; 3, medium; 4, high. For colour: 1, deep red; 2, bright red; 3, yellow red. For overall acceptability: 1, extremely liked; 2, liked; 3, moderately liked; 4, neither liked nor disliked; 5, disliked; 6, moderately disliked; 7, extremely disliked.

effectively improved by pre-heat treatment combined with a 500 ml honey concentration treatment. The best tomato ketchups were obtained from *Melkashola* variety when combined with blanching and the addition of honey at 400 and 500 ml concentrations. The chemical qualities for both varieties were found to be dependent on the methods of processing and honey concentrations. Hence, the combination of *Melkashola* variety, pre-heating, blanching treatment and 500 ml honey concentration are recommended for production of superior quality tomato ketchup.

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