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The Colour Stability and Physico-Chemical Properties of Tomato Paste Enriched with Rosella (*Hibiscus sabdariffa* L.)

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ABSTRACT

Dried Roselle calyces (*Hibiscus sabdariffa* L.) are very common commercial that could be used in the food industries, where it is abundant in anthocyanins and other bioactive compounds. The purpose of this study is to examine the impacts of adding Rosella (*Hibiscus sabdariffa* L.) *Karkadah* powder to tomato paste at concentrations of 0.3, 0.6, 0.9, 1.2, and 1.5g per 1kg of fresh tomatoes on color stability, physicochemical properties, and sensory qualities during a 60-day storage period at ambient temperature. The findings showed that adding *Karkadah* powder to the tomato paste samples raised their ash, dietary fiber, and carbohydrate content. The colour attributes of tomato paste revealed that the redness value (a*) increased while the brightness (L*) and yellowness (b*) decreased. Throughout storage, the total colour difference values (ΔE) remained the most stable, and the a*/b* ratios were at an acceptable level. Samples that included *Karkadah* had a lower pH than the control and were more acidity and contained more ascorbic acid. Total soluble solids (TSS) were nearly identical to the control at zero time. During storage, TSS and acidity increased while, pH and ascorbic acid was dropped. Out of all the tested tomato paste sample, the paste containing 0.9 and 1.2 g *Karkadah* powder showed the highest overall acceptability scores among all tested tomato paste samples at zero time and during storage. The results showed that tomato paste can be produced by adding 0.9 and 1.2g *Karkadah* powder/kg fresh tomato fruits to improve the colour without affecting the sensory properties.

Keywords: Tomato paste, *Hibiscus sabdariffa* L, Rosella, *Karkadah*, Colour stability, Physico-Chemical properties and Sensory characteristics.

INTRODUCTION

Hibiscus subdariffa L, is known as Roselle, belongs to the family *Malvaceae*, also is known as *Karkadah* in Egypt. It is grown extensively in many tropical and subtropical regions, including as Sudan, Thailand, China, Egypt, West India, and Mexico. Its original habitat is probably in West Africa (El-Saidy *et al*., 1992). Roselle juice is a widely used soft drink in several countries such as Egypt, Sudan, Mexico, Nigeria, and Thailand. It is traditionally prepared by extracting water from either fresh or dried Roselle calyxes (Aurelio *et al*., 2007).

Hibiscus subdariffa L. is a great source of anthocyanins (Inggrid *et al*., 2017). The calyces are abundant in hibiscus acid, ascorbic acid, and anthocyanins. It is water soluble with gorgeous and alluring red colour and with sour and palatable acidic taste, this plant's health benefits include aiding in digestion, having choloratic and diuretic qualities, acting as an intestinal antiseptic, and having mild laxative effects. additionally, it is used to treat clogged arteries, excessive blood pressure, and heart and nerve disorders. (Asolkar *et al*., 1992).

The anthocyanin pigment gives roselle calyces their distinctive reddish-purple colour, and have been used is in the food industry as natural substitutes to synthetic colouring additives. the red hue of anthocyanin pigments is composed of delphinidin-3-glucoside, cyanidin-3-glucoside, delphinidin-3-sambubioside and cyanidin-3-sambubioside (Borrás-Linares *et al*., 2015).

According to research by Ashaye and Adeleke (2009), the jam made with fresh calyces Roselle was more well-liked in terms of its sensory qualities. According to Henry and Badrie, 2007 study, yogurt produced with Roselle nectar had a higher level of sensory acceptance than yogurt manufactured without it. Roselle calyces were used by Bozkurt and Belibağli (2009) as a natural antioxidant component in "kavurma," a traditional meal consisting of salt, beef, and beef fat. According to Selim *et al*. (2008), the formulations with the highest acceptance rates were those with 0.2% candy and 1.0% jam of lyophilized Roselle calyces extract. Duangmal *et al*. (2004) discovered that, when Roselle calyces was encapsulated and utilized as a colorant in a refreshing drink, there was a greater overall sensory acceptability. The best colouring qualities of the encapsulated hibiscus extract were comparable to those of the control sample, which was samples dyed with E120 (Dias *et al*., 2020).

One of the most widely consumed vegetables is the tomato (*Solanum lycopersicum*), which may be used in cooking, salads, and as a raw ingredient in a variety of processed foods such sauce, puree, ketchup, tomato paste, and tomato juice (Kaur *et al*., 2008). According to Hayes *et al*. (1998), Tomato paste is a result of the evaporation of tomato pulp that contains over 24 percent soluble solids.

The colour of tomato paste and other food products is one of the most significant quality factors influencing consumer acceptance. When concentrated tomato paste is heated, several reactions may take place that change the

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colour, making it one of the most important quality factors influencing consumer acceptability of tomato paste and other food items. The most common of these include browning reactions such the Maillard reaction and ascorbic acid oxidation, as well as pigment degradation, particularly lycopene (Barreiro *et al*., 1997). Tomatoes get their characteristic red colour from lycopene, the primary carotenoid. Numerous factors, including variety, age, and agronomic and environmental conditions during growing, can influence the lycopene levels in tomatoes (Shi and LeMaguer, 2000; George *et al*., 2004 and Kaur *et al*., 2006).

In fact, there is now more interest in using natural colorants. because natural colorants are non-toxic and have positive health effects, mainly as antioxidants (Chethana *et al*., 2007 and Stintzing *et al*., 2005). The FDA (Food and Drug Administration) now only permits seven synthetic colors, down from its previous approval of seven hundred (Downham *et al*., 2000 and Chattopadhyay *et al*., 2013). Because of their detrimental effects on the environment and their connections to hazardous, poisonous, allergic, and cancer-causing reactions. The aim of this investigation was studied the effect of the incorporation of Roselle calyces (*Hibiscus subdariffa* L) *Karkadah* in tomato pastes on the physico-chemical properties, sensory attributes, and storage stability of tomato paste.

MATERIAL S AND METHODS

1. Raw materials

The dried calyces of Roselle (*Hibiscus subdariffa* L) *Karkadah* were purchased from a local market in Damanhour city, Egypt. The fresh tomato fruits were purchased from the local market, Damanhour city, Egypt.

2. Preparation of samples

The dried Roselle calyces were ground for three seconds in a CombiMax (Germany) mixer. As soon as possible, the powdered *Karkadah* was placed in polyethylene bags and stored at a low temperature (4°C) until needed.

Samples of tomato paste were made using the procedure described by Olaniran *et al*. (2015) and Koh *et al*. (2012). Freshly picked tomato fruits that were ripe and deep red were cleaned, crushed, and heated to 60°C (cold break). To produce a uniform pulp and remove the seeds and peel, the tomatoes were refined and pulped using strainers. The tomato paste was concentrated to 28–30°Bx in three stages: the first stage was 60–65°C, the second stage was 65–70°C, and the third stage was 70–75°C.

The dried Roselle calyces *Karkadah* powder was added at the last stage to prepare various samples 0.0g *Karkadah* /kg fresh tomato fruits (control sample), 0.3g *Karkadah* /kg fresh tomato fruits (S1), 0.6g *Karkadah* /kg fresh tomato fruits (S2), 0.9g *Karkadah* /kg fresh tomato fruits (S3), 1.2g *Karkadah* /kg fresh tomato fruits (S4) and 1.5g *Karkadah* /kg fresh tomato fruits (S5). After being pasteurized for three to five minutes at 105°C, the tomato pastes were cooled to 35°C, sealed in aseptic plastic bags, and left at room temperature in the dark for further estimations.

3. Chemical composition

Tomato paste samples were analyzed proximally according to the method AOAC (2006).

4. Physicochemical analysis

A digital pH-meter (Model HI 9321, HANNA instrument, Portugal) was used to measure the pH of tomato paste samples at a temperature of 25 °C. According to Ganje *et al*. (2016), the total titratable acidity was calculated in terms of citric acid. According to Jafari *et al*. (2018), a refractometer (Model ZWAJ, China) was used to measure the total soluble solids at a temperature of 25 °C. Ascorbic acid content was estimated according to the method described by AOAC (2006).

5. Colour assessment

A Hunter Laboratories spectrophotometer model (Hunter lab ULTRASCAN VIS) was used to analyze the color characteristics of tomato paste samples. L* (lightness; 0 = black, 100 = white), a* (+a* = redness, –a* = greenness), and b* (+b* = yellowness, –b* = blueness) values were used to express the results. Furthermore, the a*/b* ratio was established to define the quality of tomato paste. The calculation of ΔE for total color difference was made with the following equation:

$$\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)]^{1/2}$$

ΔL*, Δa*, and Δb* represent the differences in the colour coordinates throughout storage time and the initial values Kammerer *et al*. (2007).

6. Sensory evaluation

Twenty panelists evaluated the organoleptic characteristics of tomato paste samples. The panelists including staff, employees and students from Damanhour University's Department of Food and Dairy Science and Technology. A nine-point hedonic scale (from like very = 9 to detest excessively = 1) was used to ask the panelists to score the samples according to colour, odour, taste, texture, and overall acceptability (Olaniran *et al*., 2015). The specimens were labeled.

7. Statistical analysis method

The statistical analysis was conducted using a General Linear Model (GLM), with addition ratios as the primary impact (SAS Institute, 2017). Using Duncan's multiple range, three replicates were separated at $P < 0.05$.

RESULTS AND DISCUSSION

1 Chemical composition of dried calyces of Roselle and fresh tomato fruits

The chemical composition of powdered calyces *Karkadah* and fresh tomato fruits is shown in Table (1). The moisture content of the powdered calyces *Karkadah* was 8.9%, which was obviously very low. In contrast, the moisture content of fresh tomatoes was 92.77%, and the crude ether extract was 0.45% in fresh tomatoes and 0.18% in *Karkadah*. Fresh tomatoes had a crude protein content of 0.85%, whereas *Karkadah* had a crude protein content of 5.81%. In *Karkadah*, the corresponding ash, dietary fiber, and carbohydrate contents were 11.3%, 13.6%, and 60.13%, whereas it was 0.76%, 1.21%, and 3.93% in fresh tomatoes.

Table 1. Chemical composition of powder calyces *Karkadah* (*Hibiscus subdariffa* L.) and fresh tomato fruits.

Component %	powder calyces *Karkadah*	fresh tomato fruits
Moisture	8.9±0.31	92.77±0.36
Ash	11.3±0.28	0.76±0.08
Fat	0.18±0.15	0.45±0.03
Protein	5.81±0.04	0.85±0.11
Dietary fiber	13.6±0.15	1.21±0.09
Carbohydrates	60.13±0.34	3.93±0.13

All values are means of triplicate determinations ± standard deviation (SD).

2. Chemical composition of tomato paste samples

The proximate analysis of tomato paste samples with varied calyces *Karkadah* powder concentrations is shown in Table (2). The moisture content of the tomato paste ranged from 73.93 to 74.49%. Paste samples (S3, S4, and S5) prepared with *Karkadah* had less moisture content than the control sample. Actually, when the amount of *Karkadah* powder was increased from 0.9g to 1.5g/kg fresh tomato fruits, the moisture content of tomato pastes decreased significantly (*P*<0.05), which might be explained to reduced moisture content of *Karkadah*, since naturally dried Roselle calyces have moisture contents of 12.81% (Abou-Arab *et al*., 2011) and 11.33% (Adenipeku, 1998), while our study the moisture content of the powdered calyces *Karkadah* was 8.9%

Protein and fat percentages in tomato pastes ranged from 2.01 to 2.09 and 0.33 to 0.34%, respectively. It was observed that the addition of more *Karkadah* powder did not raise the protein or fat content of tomato pastes. This might be related to the chemical composition of *Karkadah* which, have 5.81% of protein and 0.18% fat contents. The protein and fat concentrations of all tomato pastes were found to be similar.

The carbohydrate content of the tomato paste samples varied from 16.85 to 17.71%. The pastes containing *Karkadah* (0.9, 1.2, and 1.5g/kg fresh tomato fruits) showed higher carbohydrate contents than the control sample. The addition of more *Karkadah* powder resulted in a significant (*P*<0.05) increase in the carbohydrate content of tomato pastes. According to (Cid-Ortege and Guerrero-Beltran, 2015 and Jabeur *et al*., 2017) reported that the largest content of Rosella calyces was carbohydrate followed by crude fiber and ash. The contents *Karkadah* used in study of carbohydrate, crude fiber and ash were 60.13, 13.6, and 11.3%, respectively.

The ash and fiber levels of the tomato paste samples ranged from 3.52 to 3.70 and 2.51 to 2.70%, respectively. However, adding more *Karkadah* powder resulted in a few rises in the fiber and ash content of the tomato paste samples. The current study's findings on tomato paste's chemical composition were in line with those of earlier studies (Padovani *et al*., 2007; Eke-Ejiofor, 2015 and Alqahtani *et al*., 2022).

Table 2. The proximate analysis of tomato pastes samples at different concentrations of calyces *Karkadah* powder (*Hibiscus subdariffa* L.).

Parameters (%)	Tomato paste samples Control	S_1	S_2	S_3	S_4	S_5
Moisture	74.49±0.81^{a}	74.34±0.76^{ab}	74.28±0.74^{abc}	74.06±0.82b^{bc}	73.98±0.78^{c}	73.93±0.83^{c}
Ash	3.52±0.07^{b}	3.54±0.08^{ab}	3.57±0.06^{ab}	3.62±0.06^{ab}	3.66±0.03^{ab}	3.70±0.05^{a}
Fat	0.33±0.01^{a}	0.33±0.01^{a}	0.33±0.02^{a}	0.33±0.01^{a}	0.33±0.02^{a}	0.34±0.03^{a}
Protein	2.01±0.09^{a}	2.02±0.06^{a}	2.04±0.08^{a}	2.05±0.05^{a}	2.07±0.09^{a}	2.09±0.07^{a}
Dietary fiber	2.51±0.03^{b}	2.54±0.05^{ab}	2.57±0.04^{ab}	2.62±0.06^{ab}	2.66±0.03^{ab}	2.70±0.05^{a}
Carbohydrates	16.85±0.45^{d}	16.96±0.57^{cd}	17.19±0.37^{bcd}	17.30±0.44^{bc}	17.50±0.58^{ab}	17.71±0.41^{a}

(Control): 0.0g *Karkadah* /kg fresh tomato fruits, (S1): 0.3g *Karkadah* /kg fresh tomato fruits, (S2): 0.6g *Karkadah* /kg fresh tomato fruits, (S3): 0.9g *Karkadah* /kg fresh tomato fruits, (S4) :1.2g *Karkadah* /kg fresh tomato fruits and (S5): 1.5g *Karkadah* /kg fresh tomato fruits. The values are shown as mean ± standard deviation, with n = 3. *P* < 0.05 indicates a significant difference between values with different superscripts in the same row.

2. Colour parameters

Color has a significant impact on customer acceptability and is a crucial quality factor for fruits and vegetables. Table (3) displayed the color properties of tomato paste samples with varying calyces *Karkadah* powder ratios after storage. Research revealed that adding more calyces *Karkadah* powdered addition considerably enhanced (*P*<0.05) the (redness) a* values but significantly lowered (*P*<0.05) the (lightness) L* and (yellowness) b* values of newly processed tomato pastes. Reduced L* values suggested a less brightness surface color, whereas decreased b* and increased a* values showed a less yellow and a higher red content in tomato pastes, respectively. It might be connected to how the color parameters of tomato pastes are affected by the calyces *Karkadah* powder. Abou-Arab *et al*. (2011) reported that the powdered Roselle calyces had a greater red color and a total anthocyanin concentration of 622.91 mg/100g.

The current study lab characteristics for tomato paste colour were comparable to those of Jung and Joo (2013), who found that adding 0.1−1.3% of aqueous Roselle extract to pork patties increased redness values while decreasing lightness and yellowness. Nolita *et al*. (2024), used Rosella flower to improve the properties of the Nata (made from soybean hulls) and mentioned the Nata lightness decreases with increase the concentration of Rosella flower extract. Purbowati *et al*. (2020), who showed the lightness (L*) of roselle tea colour decease by the used roselle flower petals ratio increases.

The L* values of tomato paste samples were found significantly (*P*<0.05) decrease from 20.39–26.92 to 19.38–25.18, respectively, after 0 and 60 days of storage. The a* values of paste samples papered with calyces *Karkadah* powder were nearly steady during the storage period, while the a* values of control samples showed a substantial (*P*<0.05) drop from 31.88 to 28.03, respectively. Conversely, following 0 and 60 days of storage, b* values increased somewhat (*P*>0.05) from 11.53–14.89 to 12.34–17.35, respectively. The tomato pastes that contained the calyces *Karkadah* powder were generally found to be more stable after storage in terms of color parameters than the sample control.

For tomato products, the a*/b* ratio has been used as a quality standard (Kelebek *et al*., 2017). Table (3) demonstrates that after 0 and 60 days of storage, the a*/b* ratio of the control samples dropped dramatically (*P*<0.05) from 2.14 to 1.6, respectively. However, the pastes containing calyces *Karkadah* powder showed constant a*/b* ratio values over the course of storage. According to Basak (2018), tomato pastes with an a*/b* ratio of less than 1.80 are deemed unsatisfactory. With the exception of the control sample, which recorded an a*/b* ratio of 1.61 after 60 days of storage, all samples in the current investigation showed acceptable values of the a*/b* ratio during the storage period. Control sample color changes during storage were nearly identical to those of Basak (2018), who discovered that 42 days after storage, untreated tomato paste surpassed the minimum allowable limit of the a*/b* value.

Table (3) illustrates how the arithmetic total color difference (ΔE) for tomato paste samples increased progressively as the concentration addition of calyces *Karkadah* powder increased, from 4.16 to 10.31 at zero time. During the storage period, the values of (ΔE) for all paste samples except the control tomato paste remained stable, showing no significant difference ($P<0.05$). In contrast, the values of (ΔE) for the control sample paste (Control) increased significantly ($P<0.05$) from 1.90 to 4.88 during the 20- and 60-days following storage, respectively.

During storage, tomato paste samples containing calyces *Karkadah* exhibited better parameter colour than the control sample. This could be attributed to the antioxidant properties of *Hibiscus sabdariffa* L. (Christian and Jackson, 2009 and; Farombi and Fakoya, 2005; and Mossalam *et al*., 2011); additionally, the high anthocyanin content of Rosella helped to mitigate the discoloration process during storage (Prenesti *et al*., 2007). According to Yildiz and Baysal (2007), phenolic chemicals that are naturally present in tomatoes may oxidize, which could explain why tomato paste changes in color parameters when stored. According to Basak (2018), there is a possibility that the discoloration of tomato paste samples is caused by lycopene oxidation and eventual discoloration of the tomato paste samples during storage.

Table 3. Colour parameters of tomato paste samples papered of different concentrations of calyces *Karkadah* powder (*Hibiscus subdariffa* L.) during storage.

Colour paramters	Storage days	Tomato paste samples					
		Control	**S_1**	**S_2**	**S_3**	**S_4**	**S_5**
L*	Zero	26.92±0.61^{Aa}	25.32±0.52^{Ab}	24.51±0.56^{Ac}	23.78±0.70^{Ad}	22.01±0.45^{Ae}	20.39±0.53^{Af}
	20	26.12±0.28^{Ba}	25.02±0.44^{ABCb}	24.13±0.61^{ABc}	23.46±0.53^{ABd}	21.76±0.23^{ABe}	20.04±0.43^{ABf}
	40	25.77±0.45^{Ba}	24.89±0.26^{ABCb}	23.91±0.39^{BCc}	23.05±0.63^{BCd}	21.25±0.57^{BCe}	19.79±0.91^{BCf}
	60	25.18±0.19^{Ca}	24.60±0.34^{Cb}	23.51±0.23^{Cc}	22.86±0.68^{Cd}	21.09±0.46^{Ce}	19.38±0.27^{Cf}
a*	Zero	31.88±0.43^{Af}	32.63±0.79^{Ae}	33.17±0.42^{Ad}	34.23±0.33^{Ac}	35.09±0.73^{Ab}	36.13±0.53^{Aa}
	20	30.17±0.29^{Bf}	32.31±0.63^{ABe}	33.05±0.63^{ABd}	34.09±0.42^{ABc}	34.90±0.28^{ABb}	35.97±0.19^{ABa}
	40	29.51±0.18^{Cf}	32.06±0.71^{BCe}	32.87±0.34^{ABd}	33.79±0.65^{ABc}	34.69±0.34^{ABb}	35.77±0.38^{ABa}
	60	28.03±0.62^{Df}	31.79±0.24^{Ce}	32.66±0.18^{Bd}	33.51±0.29^{Bc}	34.48±0.63^{Bb}	35.49±0.71^{Ba}
b*	Zero	14.89±0.62^{Ca}	14.08±0.36^{Bb}	13.79±0.84^{Bb}	12.85±0.18^{Bc}	12.01±0.86^{Bd}	11.53±0.58^{Cd}
	20	15.15±0.56^{Ca}	14.28±0.67^{ABb}	13.88±0.91^{ABb}	12.96±0.26^{ABc}	12.27±0.39^{Bd}	11.70±0.35^{BCe}
	40	16.72±0.28^{Ba}	14.46±0.28^{ABb}	14.01±0.80^{ABb}	13.15±0.53^{ABc}	12.53±0.16^{ABd}	12.03±0.61^{ABe}
	60	17.35±0.18^{Aa}	14.75±0.61^{Ab}	14.29±0.47^{Ab}	13.32±0.24^{Ac}	12.82±0.37^{Acd}	12.34±0.52^{Ad}
a^*/b^*	Zero	2.14±0.31^{Ac}	2.31±0.38^{Abc}	2.40±0.21^{Abc}	2.66±0.19^{Aab}	2.92±0.07^{Aa}	3.13±0.36^{Aa}
	20	1.99±0.28^{ABc}	2.26±0.21^{Ac}	2.38±0.33^{Abc}	2.62±0.26^{Aab}	2.84±0.15^{Aab}	3.07±0.27^{Aa}
	40	1.76±0.21^{ABd}	2.21±0.38^{Acd}	2.34±0.22^{Abc}	2.56±0.12^{Aabc}	2.76±0.38^{Aab}	2.97±0.33^{Aa}
	60	1.61±0.08^{Bd}	2.15±0.11^{Ac}	2.28±0.09^{Abc}	2.51±0.54^{Aabc}	2.68±0.37^{Aab}	2.87±0.15^{Aa}
ΔE	Zero	-	4.16±0.02^{Ae}	5.04±0.03^{Ad}	6.53±0.05^{Ac}	8.42±0.03^{Ab}	10.31±0.04^{Aa}
	20	1.90±0.01^{Cf}	3.96±0.03^{Ae}	5.11±0.02^{Ad}	6.54±0.02^{Ac}	8.35±0.01^{Ab}	10.38±0.03^{Aa}
	40	3.20±0.01^{Bf}	3.79±0.01^{Ae}	5.07±0.03^{Ad}	6.48±0.03^{Ac}	8.45±0.02^{Ab}	10.31±0.02^{Aa}
	60	4.88±0.03^{Af}	3.72±0.03^{Ae}	5.12±0.01^{Ad}	6.35±0.03^{Ac}	8.34±0.03^{Ab}	10.34±0.06^{Aa}

(Control): 0.0g *Karkadah* /kg fresh tomato fruits, (S1): 0.3g *Karkadah* /kg fresh tomato fruits, (S2): 0.6g *Karkadah* /kg fresh tomato fruits, (S3): 0.9g *Karkadah* /kg fresh tomato fruits, (S4): 1.2g *Karkadah* /kg fresh tomato fruits and (S5): 1.5g *Karkadah* /kg fresh tomato fruits. The values are shown as mean ± standard deviation, with n = 3. Significant differences ($P<0.05$) exist between values in the same row that have distinct lowercase superscripts. Significant differences ($P<0.05$) exist between values in the same column that have different uppercase superscripts.

3. Physicochemical Properties of tomato paste samples

Table (4) displays the results of physico-chemical analysis tests performed on tomato paste samples at various calyces *Karkadah* powder concentrations throughout storage. Tomato paste samples had total soluble solids (TSS) values ranging from 32.41 to 34.97 ºBrix. According to Abou-Arab *et al*. (2011), the amount of soluble carbohydrates in dried Roselle was low and the total soluble solids content of it was 13.5 °Brix, may be the reason why the percentage of *Karkadah* addition did not significantly enhance TSS for all sample pastes during the fresh time. Similarly, there were no appreciable variations between all treatment and control at any storage time. At day 0 and day 60 of storage, the tomato pastes TSS varied from 32.41 to 33.06 and 34.09 to 34.97 ºBrix, respectively. In general, the control and tomato paste samples TSS increased slightly during the course of the storage period. The statistical analysis revealed that the TSS rise rates for each treatment during storage were comparable to those of the other treatments. The hydrolysis of polysaccharides during storage is the cause of these increases in TSS values (Gujral *et al*., 2002). In contrast, Liu *et al*. (2010) observed variations in TSS levels in tomato powders; however, no noteworthy alterations occurred over a 5-month storage period at 0, 25, and 37°C. However, according to Basak (2018), there were no appreciable changes in tomato pastes TSS during storage.

At day 0 and day 60 of storage, the tomato paste samples had pH values ranging from 3.52 to 4.32 and 3.07 to 4.09, respectively. When tomato paste was first prepared and then stored, there was a significant decrease in the pH values. In contrast to the other sample pastes, the tomato pastes (Control, S1, and S2) were nearly stable during storage. Because rosella contains certain organic acids, such as oxalic, malic, shikimic, and fumaric acids (Jabeur *et al*., 2017), the pH values of the samples containing calyces *Karkadah* powder (S3, S4, and S5) decreased significantly when compared to the sample control. The calyxes have a very low pH of 2.10 ± 0.02 due to the high presence of acids (Salazar-González *et al*., 2012). All of the tomato paste samples pH levels were within the Codex Alimentarius recommended range, which must not exceed 4.5 (FAO, 2017). The present study findings regarding the impact of storage duration on tomato paste pH levels were consistent with prior research findings (Olaniran *et al*., 2015; Alqahtani, 2020 and Alqahtani *et al*., 2022).

At days 0 and 60 of storage, the total titratable acidity (TTA) values of tomato paste samples varied from 1.56 to 2.14 and 1.85 to 2.51%, respectively. TTA of tomato paste samples grew significantly ($P<0.05$) in all samples until 60 days of storage after being roughly steady for the first 20 days. The TTA values of paste sample(S1) and the sample control were comparable, while the TTA values of the other samples that contained calyces *Karkadah* powder increased significantly ($P<0.05$) as the addition increased. Abou-Arab *et al*. (2011) suggest that various organic acids were the cause of the acidity. According to Singh *et al*. (2017), rosella is abundant in organic acids, including citric acid, tartaric acid, malic acid, and allo-hydroxycitric acid. Our findings concurred with those of Purbowati *et al*. (2020), who discovered that adding more roselle petal blossoms decreased the pH value and significantly increased the acidity of the tea that was produced. According to Ashaye and Adeleke (2009) findings, the titratable acidity of Roselle jam rose as the storage period lengthened; this increase could have been caused by the presence of acidophiles in the jam samples. The study findings regarding the impact of storage duration on tomato paste samples TTA were consistent with prior findings (Olaniran *et al*., 2015; Alqahtani, 2020). After 60 days of storage at room temperature, the paste's TTA values, which state that TTA cannot exceed 7%, were in accordance with the international food standards given by the World Food Programme (WFP, 2011).

The ascorbic acid content (AAC) of tomato paste samples during the storage period are displayed in the same Table. The results indicated that the control sample had an AAC content of 63.63 mg/100g, and that this ratio increased gradually as more calyces *Karkadah* powder was added to the paste samples, reaching 65.73 mg/100g. It was observed that the samples with the highest AAC content were those with S3, S4, and S5, while samples with the lowest AAC content were S1 and S2, which were almost identical to the control paste.

Ascorbic acid content in Roselle calyces is high (141 mg/100 g), according to Abou-Arab *et al*. (2011). Dried Roselle calyces have an acid content of 260–280 mg/100 g (Ismail et al., 2008).

Table (4) illustrates how the ascorbic acid content (AAC) of tomato paste samples changed throughout time of storage. All samples had a significant (P<0.05) drop in AAC concentration from 63.63–65.72 to 45.61–57.92 mg/100 g after 0 and 60 days of storage, respectively.

At the end of storage, the control paste had the lowest AAC concentration (45.61 mg/100g), which could be because ascorbic acid oxidation during storage (Apaiah and Barringer, 2001). On the other hand, the tomato paste samples containing *Karkadah* had the highest ACC. According to Cid-Ortega and Guerrero-Beltrán (2014), *Karkadah* has 451.4±28.1 mg of gallic acid/100g of powdered Roselle calyces, and 37.42 mg/g of dry weight (Abou-Arab *et al*., 2011). These are examples of phenolic compounds as antioxidants. The results obtained aligned with the findings of Koh *et al*. (2012), who reported a decrease in the ascorbic acid content of tomato paste when stored at room temperature, and Ashaye and Adeleke (2009), who found that the ascorbic acid content of Roselle jam was significantly lower when stored at room temperature compared to when stored at cold temperature.

Table 4. Physicochemical Properties of tomato paste samples papered of different concentrations of calyces *Karkadah* powder (*Hibiscus subdariffa* L.) during storage.

Physicochemical Properties	Storage days	Tomato paste samples					
		Control	S_1	S_2	S_3	S_4	S_5
TSS (ºBrix)	Zero	$32.41±0.36^{Ca}$	$32.51±0.47^{Ca}$	$32.56±0.39^{Ca}$	$32.71±0.59^{Ca}$	$32.90±0.24^{Ca}$	$33.06±0.56^{Ca}$
	20	$32.92±0.53^{BCa}$	$32.97±0.69^{BCa}$	$32.98±0.78^{BCa}$	$33.11±0.37^{BCa}$	$33.41±0.24^{BCa}$	$33.52±0.80^{BCa}$
	40	$33.51±0.74^{ABa}$	$33.63±0.52^{ABa}$	$33.65±0.36^{ABa}$	$33.73±0.29^{ABa}$	$34.02±0.56^{ABa}$	$34.12±0.26^{ABa}$
	60	$34.09±0.61^{Aa}$	$34.18±0.69^{Aa}$	$34.22±0.59^{Aa}$	$34.34±0.28^{Aa}$	$34.81±0.75^{Aa}$	$34.97±0.38^{Aa}$
pH	Zero	$4.32±0.11^{Aa}$	$4.29±0.01^{Aa}$	$4.11±0.02^{Ab}$	$3.94±0.03^{Abc}$	$3.79±0.06^{Ac}$	$3.52±0.04^{Ad}$
	20	$4.28±0.09^{Aa}$	$4.20±0.03^{Aa}$	$4.03±0.05^{Ab}$	$3.81±0.05^{ABc}$	$3.59±0.01^{Bd}$	$3.31±0.02^{Be}$
	40	$4.19±0.05^{ABa}$	$4.01±0.07^{Bab}$	$3.85±0.03^{Bbc}$	$3.69±0.03^{BCc}$	$3.43±0.03^{Bd}$	$3.27±0.05^{Bd}$
	60	$4.09±0.08^{Ba}$	$3.87±0.05^{Bab}$	$3.71±0.04^{Bbc}$	$3.56±0.04^{Cc}$	$3.22±0.02^{Cd}$	$3.07±0.03^{Cd}$
Aciditiy (%)	Zero	$1.56±0.15^{Ce}$	$1.63±0.04^{Ce}$	$1.75±0.03^{Cd}$	$1.86±0.03^{Cc}$	$1.98±0.02^{Cb}$	$2.14±0.02^{Da}$
	20	$1.63±0.17^{Ce}$	$1.71±0.03^{Ce}$	$1.82±0.05^{Cd}$	$1.95±0.05^{Cc}$	$2.17±0.07^{BCa}$	$2.26±0.05^{Ca}$
	40	$1.72±0.19^{Be}$	$1.80±0.05^{Be}$	$1.93±0.02^{Bd}$	$2.10±0.02^{Bc}$	$2.26±0.04^{ABb}$	$2.35±0.03^{Ba}$
	60	$1.85±0.11^{Ae}$	$1.91±0.02^{Ae}$	$2.08±0.03^{Ad}$	$2.23±0.06^{Ac}$	$2.33±0.06^{Ab}$	$2.51±0.03^{Aa}$
Ascorbic acid (mg /100g)	Zero	$63.63±0.72^{Ad}$	$64.02±0.65^{Acd}$	$64.43±0.89^{Abd}$	$64.81±0.93^{Aab}$	$65.39±0.52^{Aab}$	$65.72±0.74^{Aa}$
	20	$59.03±0.68^{Bd}$	$61.56±0.93^{Bc}$	$62.05±0.69^{Bbc}$	$62.91±0.47^{Bb}$	$63.12±0.57^{Bb}$	$63. 90±0.58^{Ba}$
	40	$52.32±0.89^{Ce}$	$57.03±0.85^{Cd}$	$58.82±0.89^{Ccd}$	$59.32±0.68^{Cbc}$	$60.06±0.89^{Cb}$	$61.86±0.68^{Ca}$
	60	$45.61±0.77^{De}$	$53.11±0.93^{Dd}$	$54.82±0.78^{Dc}$	$55.16±0.58^{Dc}$	$56.55±0.49^{Db}$	$57.92±0.79^{Da}$

(Control): 0.0g *Karkadah* /kg fresh tomato fruits, (S1): 0.3g *Karkadah* /kg fresh tomato fruits, (S2): 0.6g *Karkadah* /kg fresh tomato fruits, (S3): 0.9g *Karkadah* /kg fresh tomato fruits, (S4) :1.2g *Karkadah* /kg fresh tomato fruits and (S5): 1.5g *Karkadah* /kg fresh tomato fruits. The values are shown as mean ± standard deviation, with n = 3. Significant differences (P<0.05) exist between values in the same row that have distinct lowercase superscripts. Significant differences (P<0.05) exist between values in the same column that have different uppercase superscripts.

4. Sensory Evaluation of tomato paste samples

The sensory evaluation considers the critical metric for potential customer preference. The sensory properties of tomato paste samples prepared with different ratios of calyces *Karkadah* powder were examined; the findings are shown in Table (5). The properties of the tomato paste samples were impacted by the increase in addition ratio. The tomato paste samples showed discernible colour differences, which the colour scores of freshly processed tomato pastes increased significantly (P<0.05) when more *Karkadah* was added. This could be as a result of *Karkadah* pigmenting effect on the finished products colour. Tomato pastes containing varying concentrations of calyces *Karkadah* powder remained relatively stable during storage, but at 40 and 60 days, there was a significant (P<0.05) difference between the paste samples and control sample, while the sample control colour score (Control) was significantly decreased. Statistical analysis showed, at 60 days of storage, the colour score of samples contents of *Karkadah* were identical. These findings are in line with a study by Nolita *et al*. (2024), who used Rosella flower to enhance the Nata's (made from soybean husks) qualities and discovered that when the concentration of Rosella flower extract was increased, the panelists preferred the Nata.

According to results of sensory evaluation, there was no discernible difference in the odour scores of newly processed tomato pastes when calyces *Karkadah* powder was added. Similarly, after being stored, the tomato paste samples containing *Karkadah* had odour scores that were identical to those of the tomato paste control.

All tomato paste samples with *Karkadah* had taste scores that were similar with the exception of tomato paste sample S5, which had a lower score when compared to the control and other tomato paste samples at 60 days of storage, which could be due the calyces Rosella are rich in anthocyanin, ascorbic acid and hibiscus acid and with sour and agreeable acidic taste (Abou-Arab *et al*., 2011). However, all samples were acceptable at 60 days of storage.

Tomato paste samples that contained calyces *Karkadah* powder had a texture scores that was roughly comparable to the control, which the texture scores of tomato pastes were unaffected by the addition calyces *Karkadah* powder.

In terms of texture scores, our findings concurred with those of Abdel-Rahman (2018), who discovered no distinctions between consistency ketchup made from tomato and ketchup made from *Karkadah*.

Overall, the tomato paste samples S3 and S4, which contained 0.9 and 1.2g of calyces *Karkadah* powder/kg of fresh tomato fruits, had the greatest acceptance scores during the storage period out of all the evaluated samples. The sensory score results from this analysis aligned with the findings of previous studies (Abdel-Rahman 2018; Alqahtani *et al.* 2022).

Table 5. Organoleptic properties of tomato paste samples prepared from different concentrations of calyces *Karkadah* powder (*Hibiscus subdariffa* L.) during storage.

Quality attributes	Storage days	Tomato paste samples					
		Control	S_1	S_2	S_3	S_4	S_5
Colour	Zero	8.00 ± 0.15^{Ad}	8.22 ± 0.09^{Acd}	8.45 ± 0.13^{Abc}	8.66 ± 0.21^{Aab}	8.75 ± 0.23^{Aab}	8.93 ± 0.026^{Aa}
	20	7.61 ± 0.07^{ABd}	7.93 ± 0.11^{Acd}	8.09 ± 0.03^{ABbc}	8.40 ± 0.03^{Aab}	8.41 ± 0.03^{Aab}	8.66 ± 0.03^{Aa}
	40	7.12 ± 0.27^{Bb}	7.76 ± 0.25^{ABa}	7.88 ± 0.25^{Ba}	7.90 ± 0.04^{Ba}	8.02 ± 0.17^{ABa}	8.11 ± 0.15^{Ba}
	60	6.53 ± 0.04^{Cb}	7.40 ± 0.32^{Ba}	7.60 ± 0.09^{Ba}	7.70 ± 0.18^{Ba}	7.76 ± 0.06^{Ba}	7.88 ± 0.31^{Ba}
Odour	Zero	8.11 ± 0.26^{Aa}	8.10 ± 0.03^{Aa}	8.12 ± 0.09^{Aa}	8.11 ± 0.02^{Aa}	8.12 ± 0.16^{Aa}	8.11 ± 0.03^{Aa}
	20	8.03 ± 0.07^{Aa}	8.04 ± 0.17^{Aa}	8.03 ± 0.03^{Aa}	8.01 ± 0.26^{Aa}	8.05 ± 0.07^{Aa}	8.03 ± 0.25^{Aa}
	40	7.92 ± 0.15^{ABa}	7.89 ± 0.08^{ABa}	7.87 ± 0.13^{ABa}	7.86 ± 0.18^{ABa}	7.91 ± 0.03^{ABa}	7.88 ± 0.05^{ABa}
	60	7.52 ± 0.03^{Ba}	7.53 ± 0.28^{Ba}	7.50 ± 0.24^{Ba}	7.51 ± 0.04^{Ba}	7.51 ± 0.34^{Ba}	7.52 ± 0.13^{Ba}
Taste	Zero	8.43 ± 0.09^{Aa}	8.45 ± 0.31^{Aa}	8.56 ± 0.27^{Aa}	8.63 ± 0.03^{Aa}	8.66 ± 0.03^{Aa}	8.25 ± 0.07^{Aa}
	20	8.19 ± 0.03^{ABa}	8.21 ± 0.03^{ABa}	8.28 ± 0.03^{ABa}	8.29 ± 0.08^{ABa}	8.33 ± 0.32^{ABa}	8.01 ± 0.34^{ABa}
	40	7.83 ± 0.14^{BCa}	7.85 ± 0.18^{BC}	7.90 ± 0.08^{BCa}	7.93 ± 0.36^{BCa}	7.95 ± 0.11^{BCa}	7.52 ± 0.03^{Ba}
	60	7.52 ± 0.26^{Ca}	7.52 ± 0.22^{Ca}	7.50 ± 0.03^{Ca}	7.50 ± 0.28^{Ca}	7.50 ± 0.29^{Ca}	7.00 ± 0.14^{Cb}
Texture	Zero	8.53 ± 0.04^{Aa}	8.62 ± 0.03^{Aa}	8.67 ± 0.09^{Aa}	8.72 ± 0.03^{Aa}	8.80 ± 0.03^{Aa}	8.87 ± 0.38^{Aa}
	20	8.19 ± 0.26^{ABa}	8.30 ± 0.38^{ABa}	8.34 ± 0.03^{ABa}	8.49 ± 0.36^{ABa}	8.62 ± 0.07^{ABa}	8.63 ± 0.08^{ABa}
	40	7.92 ± 0.37^{BCa}	7.94 ± 0.07^{BCa}	7.96 ± 0.25^{BCa}	8.01 ± 0.05^{BCa}	8.21 ± 0.39^{BCa}	8.30 ± 0.03^{BCa}
	60	7.50 ± 0.03^{Ca}	7.54 ± 0.21^{Ca}	7.65 ± 0.33^{Ca}	7.67 ± 0.29^{Ca}	7.78 ± 0.25^{Ca}	7.82 ± 0.24^{Ca}
Overall acceptability	Zero	8.12 ± 0.38^{Ab}	8.25 ± 0.32^{Ab}	8.41 ± 0.25^{Aab}	8.73 ± 0.05^{Aa}	8.77 ± 0.03^{Aa}	8.32 ± 0.34^{Ab}
	20	7.93 ± 0.15^{Ac}	8.11 ± 0.05^{Aabc}	8.35 ± 0.08^{Aab}	8.45 ± 0.19^{Aab}	8.50 ± 0.35^{Aa}	7.93 ± 0.03^{Ac}
	40	7.50 ± 0.05^{Bc}	7.67 ± 0.18^{Bbc}	7.90 ± 0.11^{Bb}	8.35 ± 0.27^{Aa}	8.39 ± 0.03^{Aa}	7.50 ± 0.16^{Bc}
	60	7.01 ± 0.09^{Cc}	7.39 ± 0.08^{Bbc}	7.52 ± 0.18^{Bab}	7.62 ± 0.08^{Ba}	7.72 ± 0.26^{Ba}	7.22 ± 0.03^{Bbc}

(Control): 0.0g *Karkadah* /kg fresh tomato fruits, (S1): 0.3g *Karkadah* /kg fresh tomato fruits, (S2): 0.6g *Karkadah* /kg fresh tomato fruits, (S3): 0.9g *Karkadah* /kg fresh tomato fruits, (S4) :1.2g *Karkadah* /kg fresh tomato fruits and (S5): 1.5g *Karkadah* /kg fresh tomato fruits. The values are shown as mean ± standard deviation, with n = 3. Significant differences (*P*<0.05) exist between values in the same row that have distinct lowercase superscripts. Significant differences (*P*<0.05) exist between values in the same column that have different uppercase superscripts.

CONCLUSION

Among all the samples that were assessed, tomato paste that contained 0.9 and 1.2g *Karkadah* powder/1kg fresh tomato fruits had the highest overall acceptance during the storage period. In conclusion, *Karkadah* powder can basically be added to tomato paste product as food colouring at concentrations between 0.9 and 1.2 g *Karkadah* per kilogram of fresh tomato fruits.

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الثبات اللونى والخواص الفيزوكيمائيه لمعجون الطماطم المدعم بالكركدية

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الملخص

تعتبركؤوس الكركديه المجففة شائعة جدا تجاريا ،ويمكن استخدامها في الصناعات الغذائية ،حيث أنها غنية بالأنثوسانين والمركبات الحيوية الأخرى. تهدف الدراسة الى تأثير إضافة مسحوق الكركدية الى معجون الطماطم بتركيزات ٠,٣ ، ٠,٦ ، ١,٢ و ١,٥ جرام لكل ١كجم عصير طماطم وذلك على الثبات اللونى ،والخواص الفيزيقية ،والكيماويه والخصائص الحسية خلال التخزين على درحة حرارة الغرفة لمدة ٦٠ يوم. أوضحت النتائج أن محتوى عينات معجون الطماطم من الرماد ،والألياف والكربوهيدرات قد ازدات بزيادة الكمية المضافة من مسحوق الكركدية. وقد أظهرت نتائج خصائص اللون لمعجون الطماطم زيادة قيم درجة الأحمرار *a ،وانخفضت قيم كل من سطوع اللون *L ، ودرجة الأصفرار *b ، أما قيم اللون (a*/b*) فكانت عند المستوى المقبول ،وقيم الأختلاف الكلى للون ΔE فكانت الأكثر ثباتا خلال التخزين. أوضحت النتائج أن معجون الطماطم المحتوى على ٠,٩ و ١,٢ جرام مسحوق كركدية مجفف/١كجم عصير طماطم كانت الأكثر تقبلا من الناحية الحسية ،وأنه يمكن الأستفادة من الكركدية كمصدر لون طبيعى والأستغناء عن الألوان الصناعية في حفظ الأغذية.

الكلمات المفتاحية: معجون الطماطم، مسحوق الكركدية ، الثبات اللونى ،الخواص الفيزيقية ،والكيماويه والخصائص الحسية.