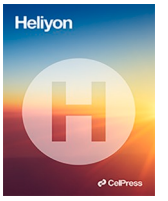
Heliyon 10 (2024) e31135

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon



Research article

Degradation kinetics of lycopene from red amaranth & preparation of winter melon jelly using this lycopene and comparison with commercial jelly

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ARTICLE INFO

Keywords:
Degradation kinetics
Lycopene
Red amaranth
Jelly

ABSTRACT

This study was conducted to observe the storage conditions, such as solvent and temperature, of lycopene content and degradation kinetics from red amaranth (*Amaranthus gangeticus*). Jelly was prepared using the extracted lycopene, the physicochemical properties and lycopene content. The extract with the maximum amount of lycopene was obtained by extraction with hexane, acetone and ethanol (2:1:1),50 ± 9 mg/kg. Higher lycopene degradation was observed at refrigerated temperature as compared to ambient temperature in hexane acetone (6:4) solvent throughout the storage periods. In this period, the initial lycopene concentration was measured to be 17 ± 8 mg/kg, whereas at the end of the storage time, it was found to be 3.0 ± 0.8 mg/kg. Hence, the results indicate that the hexane, acetone, and ethanol (in a ratio of 2:1:1) solvent method is viable for extracting and purifying lycopene from red amaranth at refrigerated temperature. This lycopene can serve as both a natural colorant and a value-added product. However, it is worth noting that lycopene can also be extracted and purified using recrystallization, column chromatography, and thin-layer chromatography (TLC) methods. The Winter melon jelly using lycopene from red amaranth contained moisture 29.6 %, ash 0.67 %, acidity 0.35 %, reducing sugar 26.8 %, non-reducing sugar 35.4 %, total soluble solid 66°brix and lycopene content 26.04 mg/kg. Proper utilization of lycopene extracted from red amaranth during the preparation of bakery, confectionary, baby food etc., may help and encourage the development of small-scale industries in the country.

1. Introduction

Red amaranth (*Amaranthus gangeticus*) is a traditional seasonal Bangladeshi vegetable with a strong red color, which is mainly available in the winter season. It is a source of large amounts of vitamins and minerals as well as folic acid, protein, dietary fiber and amino acids (Das et al., 2019). It is also an excellent source of health-beneficial bioactive compounds and different pigments such as

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https://doi.org/10.1016/j.heliyon.2024.e31135
Received 6 September 2023; Received in revised form 10 May 2024; Accepted 10 May 2024
Available online 11 May 2024

betacyanin, polyphenols, anthocyanins, lycopene and antioxidants [1–3]. Polyphenols, including anthocyanins, are part of the flavonoid family, while lycopene, beta-carotene, and betacyanin belong to the carotenoid family. Flavonoids possess free radical scavenging and antioxidative properties, which primarily contribute to reducing degenerative human diseases. Similarly, carotenoids also aid in lowering the risk of various acute and chronic diseases [4]. The statistical data shows that about 2417.61 acreage of land is under red amaranth cultivation in Bangladesh with an annual production of 3321.15 metric tons in 2020–2021, and 2379 acreage of land is under red amaranth cultivation in Bangladesh with an annual production of 3455 metric tons in 2021–2022. Due to the lack of post-harvest handling facilities, losses are as high as 14 % [5]. Winter melon (*Benincasahispida*) was utilized as a carrier for the production of lycopene jelly, which was extracted from red amaranth.

Lycopene, a non-toxic compound, demonstrates potent antioxidant properties, surpassing other carotenoids such as α-tocopherol and beta-carotene in its ability to quench free radicals [6]. It decreases the rate of the tumor, and it also may help to prevent heart diseases, cardiovascular disorders, inflammatory response, prostate cancer and deteriorative diseases [7]. Lycopene and other carotenoids improve neutral and cognitive brain functions and ocular health, protect genomic DNA integrity, lower the risk of the development of chronic diseases, and reduce bone mass, micro-architecture and strength concerning regulatory mechanisms in a postmenopausal osteoporosis model [8].

There are only six *cis*-lycopene and 72 *trans*-lycopene found in vegetables and fruits [2]. In 2003, Shi et al. observed that the degradation and isomerization of lycopene in tomato puree depend on heat and light radiation. *Cis*-isomers could be increased, and subsequently, all-trans isomers might be decreased in the dehydrated tomato prepared by various dehydration methods [9]. The level of lycopene might be enhanced in an oil-based system, and degradation and isomerization might also be affected by temperature and light irradiation [10]. Shi and Le Maguer revealedthat the loss of lycopene in tomato-based foods was influenced by bleaching, retorting, and freezing processes [9]. Lycopene stability is also influenced by other factors such as pH, enzymes, presence of oxygen, metallic ions, processing methods, intermolecular association with co-pigments, sugars, proteins, degradation products etc.), and condensation reactions [2]. Environmental factors such as temperature remarkably influence the stability of lycopene and the rate of lycopene degradation. Light and heat treatment increases the polymerization of lycopene and also degrades lycopene [2]. So, the degradation of lycopene is the main concern for consumers and food manufacturers who use lycopene as a food additive.

Previous studies informed lycopene extraction from various fruits and vegetable sources like tomato, tomato residue peels, watermelon, guavas, papaya, grapefruit, sweet red peppers, pomegranate and pumpkin [2,11–17] etc. Chromoplasts are plastids that accumulate carotenoids, including lycopene, which impart color to numerous plants, fruits, as well as certain tubers and roots. Chromoplasts in hypodermal cells, located near the surface, typically contain lycopene. The extraction method commonly involves using solvents that disrupt the cellular tissue membrane and spontaneously dissolve this pigmentation [18]. Lycopene has been extracted utilizing a reflux condensation system, an aqueous two-phase system and by using various solvents like *n*-hexane, ethyl acetate and partially soluble in acetone, ethanol and completely insoluble water [19,20]. It had been found that the degree of extraction of lycopene was highest in the case of *n*-hexane [21]. It has been reported that the utilization of methanol and acetone in the food manufacturing industry is highly forbidden because of their possible toxicity [22]. Ethanol has been considered the most preferable food application in the food industry, but a small amount of acetone is essential to extract the hydrophilic lycopene [22].

In order to describe the degradation kinetics of the lycopene in fruit and vegetables with thermal and non-thermal processes, kinetic models must be constructed to fit the experimental data. Although first-order kinetics is generally used to define the degradation of lycopene, the degradation curves usually appear to be nonlinear, exhibiting either downward (shoulders) or upward (tails) concavities [23]. The degradation kinetics and half-life model is one of the mathematical models used to define nonlinear curves, which has been found to successfully describe the survival of microorganisms in foods treated with Solvent extraction [24].

The study aims to find out how using different solvents and temperatures affects the amount of lycopene in red amaranth. It also wants to figure out the best way to extract lycopene and see how stable it is. After extracting lycopene from red amaranth, the study will make jelly with winter melon and compare it to winter melon jelly and mixed fruit jelly sold in markets.

2. Materials and methods

2.1. Sample collection and preparation

In this study, fresh red amaranth (*Amaranthus gangeticus*) and winter melon (*Benincasa hispida*) were collected from the local market of Chittagong. All the experiments are held in the Food Processing and Engineering Laboratory at Chittagong Veterinary and Animal Science University. The edible portion of amaranth was collected by washing and removing impurities and manually cut into small pieces with a stainless steel knife. Then, the red amaranth blended by a blander (PHILIPS HR1823, China) collects the juice in the biker after the filter (Whiteman No.4) and then stored at −8 °C until used.

2.2. Lycopene extraction from red amaranth

To extract lycopene from red amaranth (*Amaranthus gangeticus*), we took at least 0.5 mL of blended red amaranth and soaked it in each of three different solvent solutions—n-hexane, acetone-hexane mixture and ethanol acetone-hexane mixture, with each solution in an 8 mL tube. The solvent ratios are hexane: acetone: ethanol(2:1:1), hexane: acetone (4:6) and hexane: acetone (6:4). After 10 min of vortexes, 1.0 mL water is added to the tube and vortexes again. The extraction process was carried out for 10 min. The extract from red amaranth (*Amaranthusgangeticus)* was used for determining the total lycopene content. Subsequently, the red amaranth blended juice was kept in bikers at ambient or room temperature (30±2 °C) and refrigerated temperature (4 °C) in the study of degradation

kinetics and stability of lycopene.

2.3. Determination of lycopene content

The content of total lycopene was determined by using the modified method given by Kalpana and Kulsange [2]. Extracted red amaranth solution (8 mL) was waited for 30 min. Then, absorbance was measured at 510 nm using a spectrophotometer (U2900SM) at the optimal temperature (30 °C). The lycopene content was calculated based on the following equation (1).

$$\text{Lycopene content (mg / gm of fresh weight)} = \frac{A \times m \times S \times V}{w \times M} \quad (1)$$

where,

A = absorbance of 510 nm spectrum
m = molecular weight of lycopene ($C_{40}H_{56}$, 537 $gmol^{-1}$)
S = the volume of mixed solvent (8 mL)
V = the volume ratio of the upper layer to the mixed solvents (0.55)
w = Sample weight (0.10 g)
M = the molar extraction co-efficient (172 mM^{-1})

2.4. Assessment of lycopene degradation kinetics and stability

Red amaranth stability and degradation kinetics were examined at zero on the 4th, 8th and 12th days. The storage conditions are refrigerated temperature (4 °C) and ambient temperature (30±2 °C).

In order to investigate the lycopene pigment degradation as a function of time, the degradation speed constant (k) and half-life ($t_{1/2}$) calculations were calculated according to Equations (2) and (3), respectively [23].

$$k.t = -2.303 \times \log \frac{Atx}{Ato} \quad (2)$$

$$t_{1/2} = \frac{0.693}{k} \quad (3)$$

where:

Atx = Absorbance concerning the final time of the experiment,
Ato = Absorbance in time zero, initial time of the experiment,
k = Speed Constant (hs^{-1}),
t = Time (days, hours, minutes, seconds),
$t_{1/2}$ = half-life time.

2.5. Procedure for preparation of jelly

Processing of jelly was prepared by using the modified method given by Souza et al. [25]. Fresh red amaranth and winter melon were used to extract juice. After washing, they were cut into small pieces, and one liter of juice was extracted from the winter melon by boiling. The juice was collected and stored at a refrigerated temperature (4 °C) for further use, and the residue was discarded. The juice was heated at 60 °C for 10 min and cooled. 0.6 g potassium meta-bi-sulfate (KMS) mixed with light warm water. 50 g extracted lycopene powder from red amaranth, 20 g pectin and 1 kg sugar mixed with the extracted juice and keep heating until the total soluble solids (TSS) come to 65 %. Then, the potassium meta bi-sulfate (KMS) solution and 12 g citric acid are added to this solution and preserved in the bottle.

2.6. Physicochemical properties

Physicochemical Properties such as moisture content and acid insoluble ash content of different jellies were determined and expressed on the dry matter basis according to the procedures given in AOAC [26].

2.7. Determination of pH, percentage acidity and total soluble solids (TSS)

The pH was determined by a digital pH meter, while the total soluble solid, expressed by °Brix, was measured by a refractometer (Model no. HI 96801). The titratable acidity of the sample was determined according to the standard method described by Ranganna [27].

2.8. Determination of sugar content

Total sugars, reducing sugars and non-reducing sugars were determined according to Lane and Eynon method No.935.64 given in AOAC [26].

2.9. Statistical analysis

All measurements were carried out in triplicate for each of the samples, and averages and standard deviations were calculated from this triplicate measurement. Data were analyzed using statistical software R (windows version 2.13.1). A single-factor analysis of variance was carried out. Significant differences were estimated using Duncan Multiple Range Tests. Differences were considered to be significant at $p \leq 0.05$.

3. Results and discussion

3.1. Effects of solvent on lycopene content

This study evaluated the extraction conditions, such as solvent and temperature, on lycopene content and degradation kinetics from red amaranth. Also, the preparation of jelly using extracted lycopene from red amaranth and analysis of physicochemical properties and lycopene content of jelly samples were evaluated. The effect of solvent on lycopene content (mg/kg) under various storage conditions is shown in Table 1. The amount of extracted lycopene ranges from 20.88 to 50.19 mg/kg at various solvent conditions in zero days, where the highest value was evaluated for hexane, acetone and ethanol (2:1:1). The table illustrates the variations in extracted lycopene levels over 12 days. On the 4th day, lycopene content ranged from 7.39 to 40.60 mg/kg, with the highest value observed at 4 °C in a solution of hexane, acetone, and ethanol (2:1:1). By the 8th day, levels ranged from 6.43 to 29.32 mg/kg, with the highest values again at 4 °C in the same solvent mixture. By the 12th day, levels decreased further, ranging from 2.08 to 21.88 mg/kg, with the highest value achieved using hexane and acetone (6:4) at refrigerated temperature. At ambient temperature, the highest values were obtained on day 0, day 4, and day 8, with hexane, acetone, and ethanol (2:1:1) yielding the highest values, and on day 12, hexane and acetone (6:4) had the highest value of 3.28 mg/kg. These results were higher than papaya (15.5 ± 0.2 mg/kg) obtained by Kalpana and Kulsange [2]. A comparatively lower value of lycopene content of 23.58 mg/kg in hexane, acetone, and ethanol solvent mixer obtained by Kalpana and Kulsange and a range of 20–32 mg/kg in hexane and acetone (6:4) for papaya was found by Larissa et al. [28]. The quantification results of this study were consistent with the findings of Carvalho et al. [29], who observed that the values of lycopene content ranged from 149.6 to 191.6 mg/100 g for different tomato hybrids. These variations may be due to the variation in the origin of samples used to extract lycopene. Due to the different types of solvent utilization, the polarity of the solvent may vary greatly. Bao et al. [30] revealedthat the polarity of the solvents affected the extraction of lycopene from bacteria cells. According to Kubola and Siriamornpun [31], lycopene extraction from the oil of Gac fruit, using a mixture of chloroform and methanol, performs better than petroleum ether and hexane. Again according to Wang and Chen [21], for spray-dried powder, ethanol and hexane mixture showed better results than hexane, ethyl acetate and chloroform for lycopene extraction. Lambelet et al. [32] reported that pure lycopene is dissolved better in hexane than diethyl ether and dichloromethane. Lycopene degraded more at room temperature than at refrigerated temperature throughout the storage period for all samples [45]. Based on the data presented, it can be concluded that the lycopene content was highest when using a mixture of hexane, acetone, and ethanol as solvents, regardless of temperature. No significant differences were observed between the solvents regarding lycopene values in the samples collected on the 4th and 8th days. Discrepancies in extraction techniques and the purity of the solvents used may account for any variations.

The total lycopene content of all the extracts was decreased during the storage period. From Table 1, it was found that in the case of ambient conditions, the degradation of lycopene was faster onthe 4th day (3–4 times) than on the 8th and 12th day of storage samples. A similar statement was recorded that the lycopene contents decreased rapidly in the first week and then remained slightly stable from the second week of storage under various storage conditions [33].

The same trend was followed for lycopene degradation in refrigerated storage conditions. However, lycopene degradation was

Table 1
Effect of solvent on lycopene content (mg/kg) under various storage conditions.

Span of storage	Storage temperature	Ambient temperature (30 ± 2 °C)			Refrigerated temperature (4 °C)		
	Extracting solvent	Hexane: Acetone: Ethanol (2:1:1)	Hexane: Acetone (4:6)	Hexane: Acetone (6:4)	Hexane: Acetone: Ethanol (2:1:1)	Hexane: Acetone (4:6)	Hexane: Acetone (6:4)
0-day	Lycopene content (mg/kg)	$^{A}50\pm9^{a}$	$^{A}21\pm3^{b}$	$^{A}39\pm2^{ab}$	$^{A}50\pm9^{a}$	$^{A}21\pm3^{b}$	$^{A}39\pm2^{ab}$
4-day		$^{B}17\pm4^{bc}$	$^{B}7\pm1^{c}$	$^{B}13\pm1^{bc}$	$^{A}41 \pm 10^{a}$	$^{B}12\pm1^{bc}$	$^{B}33\pm1^{ab}$
8-day		$^{B}12.8 \pm 0.2^{b}$	$^{B}6\pm1^{b}$	$^{B}12\pm1^{b}$	$^{B}29\pm1^{a}$	$^{B}11.4 \pm 0.7^{b}$	$^{C}26\pm1^{a}$
12-day		$^{B}3.2 \pm 0.2^{b}$	$^{B}2.08 \pm 0.08^{b}$	$^{B}3.3 \pm 0.3^{b}$	$^{B}21.8 \pm 0.3^{a}$	$^{C}6.7 \pm 0.2^{b}$	$^{D}21.9 \pm 0.3^{a}$

a-c Means followed by different subscript alphabets in each row are significantly different ($P < 0.05$) among different Solvent within the same Temperature.
A-D Means followed by different subscript alphabets in each column are significantly different ($P < 0.05$) among storage duration Mean ± SD.

much slower in refrigerated conditions than in ambient conditions. Xianquan et al. [34] reported the phenomenon was close to the earlier observation of literature that the degradation rate of lycopene was faster at 37 °C as compared to 2 °C. A good correlation was found between lycopene content and storage day. There were significant differences in lycopene content between 0 and 12-day samples for both storage conditions. The results showed that the degradation was lower at the hexane acetone (6:4) solvent and the storage temperatures in this regard. Xianquan et al. [34] and Lee and Chen [35] revealed that lycopene is stable and highly colored at hexane acetone (3:2), but they gradually lose color with the increasing storage period and usually, high temperature enhances the formation of a complex oxidized degradation product such as 2-methyl-2-hepten-6-one, pseudoionone, geranial that destroys the structure of lycopene, causes the deterioration of color and makes it unstable.

3.2. Assessment of kinetic parameter of lycopene extracts from red amaranth

The thermal stability of lycopene extracted from red amaranth under various storage conditions was assessed at solvent variations. The half-life time ($t_{1/2}$) in days as kinetic parameters for the assessment of lycopene stability extracted from red amaranth was summarized in Table 2. The half-life ranges from 2.79 to 17.44 days at various solvent conditions in zero to four days, where the highest value is 17.44 at refrigerated temperature in hexane, acetone (6:4) solvent. The table also represents that from the fourth day to the eighth day, the half-life ranges from 4.71 to 16.77 at different temperature levels, where the highest value at a refrigerated temperature in hexane, acetone (6:4) solvent. From the eighth day to the twelve days, the ranges from 3.90 to 15.98 in days at a refrigerated temperature in hexane, acetone (6:4) solvent. The values of half-life time ($t_{1/2}$) for the solvents were almost the same (3–4 days) in ambient atmospheric conditions (30 ± 2 °C) onthe 4th day of storage. Sayed et al. [33] and Veazie [36] reported ranges of 168 h or 7 days for hexane, acetone, and ethanol and 240 h or 10 days for hexane, acetone mixture in watermelon. Again, the quantification value was lower than that of tomato powder (42 days or 6 weeks), as found by Anguelova and Warthesen [37]. Again, Sayed et al. [33] and Anguelova and Warthesen [37] revealed in refrigerated storage conditions (6 °C), values for half-life time ranges from 7thto 42 days for hexane, acetone and 76–132 days for hexane, acetone, ethanol in 7th day of storage. Xianquan et al. [34] and Lee and Chen [35] presented the variation in $t_{1/2}$ values for both the solvents and storage condition might be due to the difference in storage time and treatments and also the origin of the sample used to extract lycopene. It had been observed that the half-life ($t_{1/2}$) values for hexane acetone (6:4) were 2–3 times higher in refrigerated storage conditions than in normal atmospheric conditions. Again, for hexane, acetone, and ethanol, it was 2–3 times higher in refrigerated storage conditions than in normal atmospheric conditions (Table 02). This is probably due to the effect of temperature and extraction solvent on lycopene stability. Our findings follow the earlier recorded statement that lycopene was shown by Anguelova and Warthesen [37] to be more stable at a temperature of 6 °C with higher half-life values and showed lower half-life values at a temperature of 45 °C. The stability of lycopene at high temperature or normal atmospheric temperature is known to be most affected by many environmental factors such as light, heat, dehydration, and the presence of oxygen, which are likely to differ depending on the processing condition and also the origin of samples were found by Xianquan et al. [34] and Lee and Chen [35]. Many processing factors, as well as environmental factors, are also responsible for the degradation of lycopene pigment. Hence, it is not unexpected that the fluctuated value of half-life time ($t_{1/2}$) was noticed throughout the entire storage study. It was observed that a better result for half-life ($t_{1/2}$) was obtained in hexane acetone (6:4) at lower pH in refrigerated storage conditions. The effects of storage temperature on the stability of lycopene may probably be responsible for this.

Normally, a high constant value of degradation rate represents the fast degradation of a molecule. However, this trend can be different due to various factors such as solvent polarity, pH, moisture content, molecule size, soluble solid content, etc., which cause increments or decrements in the reaction rate [33]. In this study, a similar trend was not found. According to Kirca and Cenoroglu [38], the number of molecules increased, and the reaction rate accelerated. In this study, the values of half-life ($t_{1/2}$) for all samples were 13.66–72.18 days, which was much higher than the lycopene from tomatoes reported by Demiray et al. [39]. There is limited information available in the literature studies on the half-life of red amaranth lycopene. Usually, the lycopene half-life is smaller when extracted at higher temperatures than when extracted at lower temperatures [33].

3.3. Composition of different jellies

The winter melon jelly was analyzed for moisture, acid-insoluble ash, acidity, reducing sugar, non-reducing sugar, total sugar, total

Table 2
Half-life (t1/2) time values in days as kinetic parameters for lycopene degradation from red amaranth under various conditions.

Span of storage	Storage temperature	Ambient temperature (30 ± 2 °C)			Refrigerated temperature (4 °C)		
	Extracting solvent	Hexane: Acetone: Ethanol (2:1:1)	Hexane: Acetone (4:6)	Hexane: Acetone (6:4)	Hexane: Acetone: Ethanol (2:1:1)	Hexane: Acetone (4:6)	Hexane: Acetone (6:4)
4-day	Half-life time ($t_{1/2}$) (days)	$^{A}3.0 \pm 0.8^{c}$	$^{B}3.\pm0.2^{c}$	$^{B}2.8 \pm 0.3^{c}$	$^{A}14\pm5^{ab}$	$^{B}6\pm2^{bc}$	$^{A}17\pm8^{a}$
8-day		$^{A}4.7 \pm 0.7^{c}$	$^{A}5.3 \pm 0.3^{c}$	$^{A}5.2 \pm 0.6^{c}$	$^{A}13\pm4^{ab}$	$^{A}11\pm2^{b}$	$^{A}17\pm4^{a}$
12-day		$^{A}3.9 \pm 0.7^{c}$	$^{A}5.1 \pm 0.7^{c}$	$^{A}4.7 \pm 0.6^{c}$	$^{A}12\pm6^{ab}$	$^{A}11\pm1^{b}$	$^{A}16\pm2^{a}$

a-c Means followed by different subscript alphabets in each row are significantly different ($P < 0.05$) among different solvents within the same Temperature.
A-B Means followed by different subscript alphabets in each column are significantly different ($P < 0.05$) among storage duration Mean ± SD.

soluble solids (TSS), and pH.The compositions of different types of jellies are represented in Table 3. The result showed that the moisture content of winter melon jelly using lycopene extracted from red amaranthwas 29.56 %.This value was comparable to that found by Ali and Alghamdi [40], who reported moisture content in date jelly at 31.5–31.7 %, Ellen et al. [41], who reported moisture content in jambolan jelly at 25 % and Islam et al. [42], who reported moisture content in dragon fruit jelly 9.3–13.1 %. The difference in moisture value in different fruit jellies might be due to the variation in moisture content in fruit processing techniques.

The ash content of winter melon jelly using lycopene extracted from red amaranth was 0.67 %. This value was comparable to that found by Rasheda [43], who reported that the ash content in guava jelly was 0.69 %. Again, the value was comparable to that found by Ali and Alghamdi [40], who reported ash in date jelly 0.29–0.30 % and Islam et al. [42], who reported ash in dragon fruit jelly 0.62 %.

From Table 03, we found that the acidity of winter melon jelly using lycopene extracted from red amaranth was 0.35 %. This value was comparable to that found by Rasheda [43], who reported that guava jelly had 0.31 % acidity.

The reducing sugar, non-reducing sugar, and total sugar content of winter melon jelly using lycopene extracted from red amaranth was 26.75 %, 35.45 % and 64.05 %, respectively. The value was comparable to that found by Ellen et al. [40], who reported reducing sugar, non-reducing sugar, and total sugar in jambolan jelly were 29 %, 39 % and 68 %, respectively, and Islam et al. [42], who reported reducing sugar, non-reducing sugar and total sugar content in dragon fruit jelly were 27.36 %, 36.99 % and 64.20 % respectively. This value was comparable to that found by Rasheda [43], who reported reducing sugar, non-reducing sugar, and total sugar content in guava jelly were 29.1 %, 8.23 % and 37.33 %, respectively.

The result showed that the lycopene content of the winter melon jelly using lycopene extracted from red amaranthwas 26.47 mg/kg, where as winter melon jelly and mixed fruit jelly from markets has no lycopene because winter melon is a colorless fruit that contains no pigments; mixed fruit jelly from markets also contain no pigments because they were manufactured normally utilizing various flavor and color agents (synthetic azo dye) such as Orange Flavoring, mango flavoring, E102 (Tartrazine = Lemon yellow), E110 (sunset yellow), E142 (Green S), E160 (Toyota Corolla), E161 (Canthaxanthin), E162(Beetroot red) which has no natural pigments. Gupta [44] reported 16.05 mg/100 g lycopene content in tomato juice. From this study, we can determine lycopene can be used as a natural antioxidant and color in different confectionary items.

From the above discussion and the table, it is very difficult to differentiate winter melon jelly using lycopene extracted from red amaranth from winter melon jelly and mixed fruit jelly from markets utilizing moisture content, ash, acidity, reducing sugar, non-reducing sugar, total sugar content, total soluble solid (TSS) because they are all the same for any kinds of jellies. In this study, we only differentiate winter melon jelly using lycopene extracted from red amaranth from winter melon jelly and mixed fruit jelly from markets by color and lycopene content.

4. Conclusion

In this research work, lycopene was successfully extracted, and the effects of various parameters (extraction media and storage conditions) on total lycopene content and stability of lycopene were also investigated from red amaranth. Extraction with hexane, acetone and ethanol (2:1:1) provided a higher amount of lycopene content and better thermal stability obtained at refrigerated storage conditions (4 °C) than ambient atmospheric conditions (30 ± 2 °C). Also, in this study, the moisture content, ash content, acidity, reducing sugar, non-reducing sugar, total sugar content, TSS and lycopene content of winter melon jelly with extracted lycopene were investigated. The results showed that winter melon jelly exhibited good lycopene content. Therefore, it can be concluded that this study would help the potential use of lycopene from red amaranth as a natural source of antioxidants and natural colorants for the food industry to avoid the carcinogenic effect of synthetic colorants. Unlike β-carotene, it does not have provitaminA activity. It is readily absorbed from different food sources, distributes to different tissues and maintains its antioxidant properties in the body. It is suggested that it has anti-cell-proliferative, anti-carcinogenic, and anti-atherogenic activities.

Data availability statement

All data are updated in the supporting information file section in the editorial manager.

Table 3
Composition of Winter melon jelly using lycopene from Red Amaranth, Sole winter melon jelly and mixed fruit jelly from markets.

Parameter	Winter melon jelly using lycopene extracted from Red Amaranth	Winter melon jelly	Mixed fruit jelly from markets
Moisture content (%)	29.56 ± 0.02^{b}	29.26 ± 0.05^{b}	31.6 ± 0.5^{a}
Ash (%)	0.67 ± 0.01^{a}	0.65 ± 0.05^{ab}	0.60 ± 0.02^{b}
Acidity (%)	0.35	0.36	0.40
Reducing sugar (%)	26.8 ± 0.1^{a}	25.3 ± 0.1^{b}	24.8 ± 0.1^{b}
Non-reducing sugar (%)	35.5 ± 0.2^{a}	36.5 ± 0.2^{a}	35.53 ± 0.08^{a}
Total sugar content (%)	62.2 ± 0.3^{a}	61.7 ± 0.3^{a}	60.28 ± 0.03^{b}
Total soluble solid (°brix)	66	66	65
Lycopene (mg/kg)	26.5 ± 0.2^{a}	00.00^{b}	00.00^{b}

a-c Means followed by different subscript alphabets in each row are significantly different ($P < 0.05$) among different types of jelly.

CRediT authorship contribution statement

Md. Asaduzzaman: Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Nazmul Hasan:** Writing – review & editing. **Kohinoor Begum:** Writing – review & editing. **S.M. Ziaul Hoque:** Methodology.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:Md. Asaduzzaman reports administrative support was provided by State University of Bangladesh.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e31135.

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