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Production of Beverages with Nutritional Value for Some Sensitive Groups

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ABSTRACT

Vitamin A deficiency affects millions of children and pregnant women, leading to severe symptoms and even death. It is a significant contributor to anemia due to its role in blood formation, iron absorption, and overall immune function. Fatalities associated with vitamin A insufficiency are often indirectly caused by anemia. This study aimed to evaluate the nutritional value of drinks made from carrots, sweet potatoes, and tomatoes, considering their potential to address vitamin A deficiency and anemia-related issues. Five recipes were developed, varying the weight ratios of the ingredients. Sugar and water were added to achieve a Brix concentration of 14° and the beverages were pasteurized. After six months of storage at room temperature, recipe R2 demonstrated the best physical, chemical, and sensory properties. One serving (100 ml) of this beverage contains a high amount of vitamin A (3010iu), which is adequate for most individuals, except for pregnant and lactating women, who are advised to consume double the amount (200 ml). However, it falls short of meeting the daily requirements for vitamin C, iron, copper, and folate. Nevertheless, when paired with meals including edible oils like sunflower oil, it can help improve iron absorption. This natural drink offers a promising solution for individuals dealing with vitamin A deficiency or anemia, particularly when incorporated into a balanced diet.

1. Introduction

Vitamin A deficiency is a significant global health concern (Souganidis et al., 2013), affecting millions of school-aged children and pregnant women in developing and low-income countries. This deficiency leads to malnutrition, mortality, deteriorated health status, slower tissue development, delayed metabolism, and increased susceptibility to infectious diseases (Sommer, 2008). Vitamin A deficiency is one of the leading causes of poor health and malnutrition among young children in Africa (Zhao et al., 2022). It affects around 50% of children aged 6 to 59 months and pregnant women, particularly in low-income countries, and more than half of children with severe vitamin A deficiency die. In addition to stunted growth, vitamin A deficiency can cause liver disease, absorption issues, night blindness, dry skin, and complications in the linings of the intestines, bladder, and lungs (UNICEF, 2024 and Bhatte et al., 2024). In many countries, vitamin A deficiency is a cause of early mortality among infants and children aged 5 to 6 years, as well as blindness in pregnant women and girls. Insufficient vitamin A intake has also been identified as a factor in anemia (Khor, 2005 and Khan et al., 2007) and it is suggested that vitamin A deficiency contributes to anemia by affecting hematopoiesis and improving susceptibility to common illnesses (Semba et al., 1992; Semba and Bloem, 2002). The majority of the findings of various studies show that all deaths and adverse effects of vitamin A deficiency are indirectly connected to anemia, reduced iron absorption, which leads to iron deficiency anemia and a higher mortality risk (Sommer and Vyas, 2012). The causes of anemia include iron deficiency, malaria, certain unavoidable illnesses, and poor overall

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health, which ultimately affect hemoglobin and vitamin A levels in the body. Anemia, characterized by a deficiency of red blood cells and hemoglobin, reduces the body's ability to transport oxygen to vital organs through the bloodstream. Various factors contribute to anemia, such as deficiencies in iron, copper (which aids iron absorption), and vitamin C (WHO, 2008). While iron deficiency is the most common cause of anemia (Latham, 1997), deficiencies in vitamin B-12, folate, vitamin A, and even zinc can also lead to anemia in mothers, either individually or in combination (Van den Broek and Letsky, 2000). However, combining iron and vitamin A supplementation in pregnant women has been shown to improve both vitamin A and iron levels (Suharno et al., 1993). The primary factors contributing to the prevalence of vitamin A deficiency are inadequate intake and poor absorption, which are influenced by socioeconomic status and socio-cultural barriers (Akhtar et al., 2012). One important strategy to combat vitamin A deficiency is to consume plant sources rich in vitamin A precursors or use them in food fortification (Wu et al., 2021). Plant sources rich in β-carotene, a precursor of vitamin A—such as carrots, sweet potatoes, and tomatoes—play a crucial role in providing essential nutrients for health. These foods are significant sources of vitamin A, helping increase hemoglobin levels in the blood due to their β-carotene content (Mielech et al., 2020). Carrots, sweet potatoes, and tomatoes are also rich in antioxidants, particularly β -carotene, which has various biological benefits, including reducing mortality (Fedacko et al., 2019). In addition to promoting tissue growth and repair, these foods help combat infections, protect vision, prevent eye diseases, and reduce the risk of various illnesses and cancers (Bacchetti et al., 2019). They are also high in iron, copper, potassium, vitamin C, and folic acid, all of which aid iron absorption, boost immune function, protect against infections, and prevent anemia. A single tomato provides 27-33% of the daily vitamin C requirement for adult men and women (Garavand et al., 2019 and Harwansh et al., 2019). Sweet potatoes are rich in essential nutrients such as vitamins C and E, B vitamins, iron, zinc, potassium, and fiber (Gelaye, 2024). A 100-gram serving of sweet potatoes provides 35% of the daily vitamin C requirement, 385% of the vitamin A requirement, and 27% of the daily potassium requirement, along with additional fiber, vitamins, and minerals (Fernandez-Orozco et al., 2013). β-carotene, derived from natural sources, is converted into two molecules of vitamin A in the animal body, where it is stored as retinyl ester (O'Byrne and Blaner, 2013). Biologically, one international unit (IU) of vitamin A is equivalent to 0.3 µg of retinol or 0.6 µg of β-carotene. The recommended daily intake for males is typically 900 micrograms of retinol or 1,800 micrograms of β-carotene, which equals 3,000 IU, while for females, it is 700 micrograms of retinol or 1,400 micrograms of β-carotene, equivalent to 2,330 IU of vitamin A (IM, 2001). Developing new products by combining two or more types of vegetables can increase market appeal, enhance color and flavor, and reduce production costs (De Carvalho et al., 2017). This study evaluates the nutritional value of beverages made from a blend of carrots, sweet potatoes, and tomatoes, and how well they meet the nutritional needs of individuals suffering from vitamin A deficiency or deficiencies that cause anemia.

2. Materials and Methods

Materials

Chemicals

DPPH, Folin-Ciocalteu reagent, and all analytical-grade solvents and chemicals were supplied by Sigma-Aldrich Corporation.

Vegetables

Fresh carrots (*Daucus carota L.*), sweet potatoes (*Ipomoea batatas L.*), and tomatoes (*Lycopersicum esculentum*) were purchased from a local market in Ismailia, Egypt.

Starting Materials

Sugar and citric acid, used in the preparation of the drinks, were obtained from local markets in Ismailia, Egypt.

Preparation of Pulps

The preparation process began by thoroughly

The vegetables were then immersed in boiling water for 20 minutes. Carrots were pulped using a hand mixer, while sweet potatoes were peeled and mashed. Fresh tomatoes were washed and air-dried, and their juice was extracted using a Moulinex juice extractor, followed by filtering through strainers.

Drink Preparation

The carrot roots, sweet potato tubers, and tomato pulps were blended according to the proportions outlined in Table 1.

Table 1. Recipes for drinks

Recipes	Carrot: sweet potato: tomato pulps	Total pulp/100ml drink	Final brix
R1	10 : 4g : 4g	18 g	14
R2	8g : 6g : 4g	18 g	14
R3	7g : 7g : 4g	18 g	14
R4	6g : 8g : 4g	18 g	14
R5	4g : 10g : 4g	18 g	14

In this study, sugar and water were used to adjust the concentration to 14°Brix. Sodium benzoate (1g/l) was added as a preservative, and citric acid was used to adjust the pH to 4 (Ibrahim and El-Dreny, 2022). The drinks were pasteurized at 85°C for 25 seconds, sealed, and placed in a water bath at 85°C for 2 minutes. The bottles were then cooled to room temperature using cold water and stored at room temperature (Ibrahim and Khashaba, 2020). Samples were analyzed after processing and every two months thereafter.

Method

Proximate Analysis

Proximate analysis, including moisture, crude protein, crude fat, crude fiber, and total ash, was conducted according to AOAC (2005). Total carbohydrates were estimated using the following equation: Available carbohydrates = 100 - [moisture + protein + fat + fiber + ash].

Brix (TSS)

Abbe refractometer (USA) C10 at 20°C was used to determine Brix degree.

pH values

A pH meter Jenway 510 (UK) that calibrated with buffers at pH 4.0 and pH 7.0 was used to determine the pH.

Titratable acidity

NaOH at 0.1N was used to titration the drinks to determine acidity as % citric acid according to AOAC (2000).

Ascorbic acid

2,6- Dichlorophenolindophenol used to calibrate ascorbic acid to a pink color and calculated as mg/100g drink according to (Ranganna, 2009).

Total phenolic content (TPC)

PC was estimated by Osorio-Esquivel et al. (2011) using the Folin-Ciocalteu reagent and expressed in milligrams of gallic acid equivalent per gram of sample.

Antioxidant Activity (AA)

Antioxidant activity was determined using the Diphenylpicrylhydrazyl (DPPH) method as described by Brand-Williams et al. (1995).

β-Carotene

β-Carotene content was determined using a 6:4 v/v mixture of hexane and acetone, as outlined by Barros et al. (2011).

Folate

Folate analysis of the beverage samples was performed using HPLC, following the method described by Jastrebova et al. (2003).

Browning (Alcohol-Soluble Color)

Browning was determined using the method outlined by Ranganna (2010).

Color Estimation

Color attributes, including lightness (*L**), redness to greenness (*a**), and yellowness to blueness (*b**), were measured using a Minolta CR-10 color reader (Inc., Osaka, Japan).

Minerals Analysis

Iron (Fe) and copper (Cu) were determined using atomic absorption spectroscopy, following the AOAC (2005) method.

Microbiological Analysis

Recipe samples were analyzed for microbial load using the serial dilution and plating technique. A 25mL beverage sample was homogenized in 225mL of 0.1% peptone water. Total bacterial count (TBC) and yeast and mold count (YMC) were determined using appropriate dilutions on nutritional agar and potato dextrose agar. The plates were incubated at 37°C for 48 hours for TBC and 25°C for 5 days for YMC. The mean values were reported as log cell forming units (CFU) per milliliter.

Sensory Attributes

Sensory assessments of several beverages were conducted by a panel of ten semi-trained panelists using the Howard and Dewi (1995) approach for taste, odor, color, mouthfeel, and appearance. Overall acceptability was calculated as the mean of all scores.

Statistical Analysis

ANOVA analysis was applied to the data using COSTAT (CoHort software version 6.303), and the means were compared using Duncan's test at P = 0.05.

3. Results and Discussion

The proximate analysis and chemical composition of carrot, sweet potato, and tomato pulps

Carrots are a low-glycemic food with a glycemic index of 16-55, offering numerous health benefits, especially for diabetics (Sun et al., 2015). They are primarily composed of carbohydrates (10.1%) and water (84.9%), with appropriate amounts of protein, fats, and minerals. Carrots have around 41 calories per 100 grams carrots are a rich source of dietary fiber, contributing to healthy weight maintenance and reduced heart disease risk. They are also an excellent source of minerals and vitamins. A 100g sweet potato contains 85.8 calories, 75.2% water, 1.6g of protein, 20.1g of carbohydrates, 1.8g of fiber, and 0.3g of fat. Each 100g of raw tomatoes provides 18 calories, 92.7g of water, 0.9g of protein, 0.2g of fat, 3.8g of carbohydrates, and 1.2 grams of fiber. Carrots, sweet potatoes, and tomatoes are all rich in β-carotene, which is converted into vitamin A in the intestines. Provitamin A (PVA), a precursor to vitamin A, is primarily found in leafy vegetables and yellow fruits (Strobel et al., 2007 and Imdad et al., 2022). Biologically, one international unit of vitamin A is equivalent to 0.3μg of retinol or 0.6μg of β-carotene. The daily recommended intake for males is typically 900 micrograms of retinol or 1800 micrograms of β-carotene per day, equivalent to 3,000 international units, while for females it is 700 micrograms of retinol or 1400 micrograms of β-carotene per day, equivalent to 2,330 international units of vitamin A (IM, 2001). Based on the β-carotene data in the table, 100g of carrots, sweet potatoes, or tomatoes exceed the body's daily requirements by 430%, 190%, and 50%, respectively. Vitamin C enhances iron absorption and immune system function. The recommended daily allowance (RDA) of vitamin C is 90mg for adult males, 75mg for adult females, and 120 milligrams for pregnant women aged 19 and older. According to the vitamin C quantities in the table, 100 grams of carrots, sweet potatoes, or tomatoes provide 20%, 32%, and 48% of the body's daily requirements, respectively. The iron content in 100 grams of each type of vegetable surpasses the daily needs of children up to 12 months. For children over a year old, adults, and the elderly, 100 grams of each type of vegetable provides 10-35% of the daily iron needs. Copper is an essential mineral for overall well-being, present in every body tissue. It plays a role in red blood cell formation, enzyme production, nerve cell health, immune system function, collagen production, iron absorption, and energy generation. The daily copper need varies with age. Adults should consume 900 micrograms (mcg) of copper per day, with a maximum of 10,000 mcg (10mg) for those aged 19 and over. The data presented in the table show that 100g of various vegetables provide 33-78% of the daily copper needs. However, they only provide 2.75-4.75% of the recommended daily folate consumption (approximately 400 micrograms per day).

Table 2. The proximate analysis and chemical composition of carrot, sweet potato, and tomato pulps on wet weight basis

Analysis	Carrot	Sweet Potato	Tomato
Proximate analysis			
Moisture%	84.9	75.2	92.7
Available carbohydrate %	10.1	20.11	3.8
Protein%	0.9	1.6	0.9
Fat%	0.2	0.3	0.2
Total Ash%	1.1	0.99	1.2
Crude Fiber %	2.8	1.8	1.2
Antioxidant and minerals			
Carotenoids (β-carotene) µg/g	258	115.1	4.49
Vitamin C mg/g	0.15	0.234	0.3616
Folate (Vitamin B9) µg/g	0.19	0.11	0.15
Fe mg/g	0.022	0.0081	0.028
Cu mg/g	0.003	0.007	0.0067

Effect of storage on remaining vitamin A units equivalent to the amount of β -carotene in each recipe

Table 3 shows the β-carotene content per 100 mL of drink, the equivalent international units of vitamin A, and the percentage of vitamin A remaining after 6 months of storage. The data indicate that the β-carotene percentage increased with the higher proportion of carrots in the recipe, as observed in Recipe R1. Conversely, β-carotene content decreased with a reduction in carrots and an increase in sweet potatoes, reaching the lowest level in Recipe R5. Notably, after pasteurization, Recipe R3 retained the highest percentage of β-carotene concentration (87.9%) of the original value and the highest percentage after 6 months of storage (67.7%), equivalent to 2966 IU of vitamin A.

Table 3. Effect of storage on remaining vitamin A units equivalent to the amount of β -carotene in each recipe

			Months			
		β-carotene in fresh drink (µg/100ml)	0	2	4	6
R1	β-carotene (µg/100ml)	3058^a	2651^a	2376^a	2174^a	1771^b
	Equivalent IU* of V.A		4421	3960	3623	2952
	Remaining after loss%		86.7	77.7	71.1	57.9
R2	β-carotene (µg/100ml)	2773^b	2432^b	2171^b	1985^b	1806^a
	Equivalent IU of V.A		4053	3618	3309	3010
	Remaining after loss%		87.7	78.3	71.6	65.1
R3	β-carotene (µg/100ml)	2630^c	2312^c	2134^c	1969^c	1780^b
	Equivalent IU of V.A		3854	3556	3282	2966
	Remaining after loss%		87.9	81.1	74.9	67.7
R4	β-carotene (µg/100ml)	2487^d	2098^d	1857^d	1724^d	1477^c
	Equivalent IU of V.A		3497	3095	2874	2462
	Remaining after loss%		84.4	74.7	69.3	59.4
R5	β-carotene (µg/100ml)	2201^e	1799^e	1558^e	1312^e	1009^d
	Equivalent IU of V.A		2997	2597	2186	1682
	Remaining after loss%		81.7	70.8	59.6	45.8

* One international unit of vitamin A is equal to 0.6 µg of β-carotene according to (IM, 2001)

a-b Means with distinct superscript alphabets in each column are substantially different between treatments.

Recipe R2, however, provided the greatest amount of vitamin A (3010 IU), exceeding the daily requirements for men (3000 IU) and women (2330 IU). Over the six-month storage period, β-carotene levels in all recipes exhibited a similar declining trend, attributed to auto-oxidative degradation or isomerization (Alkesh et al., 2005; Sharma et al., 2009). Dhiman et al. (2017) reported similar findings for pumpkin drinks. Given that vitamin A deficiency can contribute to anemia through various mechanisms, including its role in erythropoiesis, immune function, and iron metabolism (Semba and Bloem, 2002), the drinks from Recipes R2 and R3 are particularly suitable for patients with anemia caused by vitamin A deficiency. At the end of the storage period, 100 mL of these drinks from Recipes R2 and R3 meet the daily vitamin A needs for both men and women.

Effect of storage on the residual units of vitamin A that are equivalent to β -carotene

Table 4 shows how many IU of vitamin A equivalent to β-carotene are present in each 100 mL of drink. As previously indicated, 100 ml of a recipe R2 or R3 approximately covers an adult's daily vitamin A equivalent need, whether male and female. Consuming a whole package (200 ml) of either R2 or R3 recipes increases vitamin A IU by almost twice. When two packets (400 ml) are taken in every day, the consumption of vitamin units increases to approximately four times what the body requires.

Table 4. Effect of storage on the residual units of vitamin A that are equivalent to β -carotene in 100 mL drink

	Equivalent units of Vitamin A (IU) in 100 mL drink			
	0	2	4	6
R1	4421[a]	3960[a]	3623[a]	2952[c]
R2	4053[b]	3618[b]	3309[b]	3010[a]
R3	3854[c]	3556[c]	3282[c]	2966[b]
R4	3497[d]	3095[d]	2874[d]	2462[d]
R5	2999[e]	2597[e]	2186[e]	1682[e]

[a-b] **Means with distinct superscript alphabets in each column are substantially different between treatments**

Percentage of average daily intake of vitamin A units (β-carotene equivalent) from consuming 100 ml drink of various recipe for various groups during storage

Table No. 5 shows the percentage of vitamin A obtained daily as a result of consuming 100ml drink of different recipes stored for six months at room temperature for the different categories. For children aged 1-3 years, a 100 ml drink after 6 months of storage from recipe R2 (containing the maximum concentration of β-carotene) provides the body with three times the vitamin A equivalent units needed (301 %). In cases when more vitamin A is required, such as in pregnant or breastfeeding women, 100 mL of R2 drink after 6 months of storage provides just 69.5% of the daily need. As a consequence, it is preferable to raise the amount consumed to 200 ml (one bottle) per day, which would cover the daily needs by 139% in such instances. Increasing the quantity of vitamin A consumed by women in general, pregnant and breastfeeding women in particular, is extremely beneficial because females are always more vulnerable to vitamin A deficiency and anemia than men in practically all geographical locations and age groups (Kassebaum et al., 2014). Based on this, we conclude that 100 ml of the drink from the prepared recipes, particularly R2, meets the body's daily vitamin A requirements for all groups, with the exception of pregnant and breastfeeding women, who must double the amount of drink consumed daily to reach 200 ml, which is equivalent to one bottle.

Table 5. Percentage of average daily intake of vitamin A units (β-carotene equivalent) from consuming 100ml drink for various groups during storage

	100ml Drink											
	0 month	2 months	4 months	6 months	0 month	2 months	4 months	6 months	0 month	2 months	4 months	6 months
	Age (1-3 years)				Age (4-8 years)				Age (9-13 years)			
R1	442%	396%	362%	295%	590%	528%	483%	394%	884%	792%	724%	590%
R2	405%	362%	331%	301%	540%	483%	441%	401%	811%	724%	662%	602%
R3	385%	356%	328%	297%	514%	474%	438%	396%	771%	711%	656%	593%
R4	350%	310%	287%	246%	466%	413%	383%	328%	699%	619%	575%	492%
R5	300%	260%	217%	168%	400%	346%	292%	224%	600%	519%	437%	336%
	Teenage girls				Teenagers				Pregnant and breastfeeding women			
R1	190%	170%	156%	127%	147%	132%	121%	98%	102%	91%	84%	68%
R2	174%	155%	142%	129%	135%	121%	110%	100%	94%	84%	76%	70%
R3	165%	152%	141%	127%	129%	119%	109%	99%	89%	82%	76%	69%
R4	150%	132%	123%	106%	117%	103%	96%	82%	81%	71%	66%	57%
R5	129%	111%	94%	72%	100%	87%	73%	56%	69%	60%	51%	39%

The amount of vitamin C, iron, copper, and folate in the fresh drink made from different recipes

Table 6 presents the levels of vitamin C, folate, copper, and iron in 100 mL of fresh drink. These elements are closely linked to anemia, a nutritional deficiency that occurs when the body lacks sufficient nutrients for red blood cell production or maintenance (Balarajan et al., 2011). Common dietary deficiencies causing anemia include vitamin A, B12, B6, C, D, E, folic acid, riboflavin, iron, copper, and zinc (Wieringa et al., 2016). The fresh drink data in Table 6 shows that the vitamin C content in the five recipes did not reach 5 mg/100 mL, and two bottles (400 mL) did not meet the recommended daily intake for women (17 mg) or men (18 mg). Regarding iron, the drink only meets the daily needs of children up to six months. For other age groups, consuming up to 400 mL of the drink does not meet the daily iron requirement, which ranges from 7 to 18 mg. The daily copper need is estimated to be 0.9 mg, and two bottles of the drink provide only one-third to one-half of that amount. Additionally, the folate supply in the drink is inadequate. The daily folate requirement is 400 µg, while two bottles provide only 12 µg per day. Based on the available data, we can conclude that the drink prepared from carrots, sweet potatoes, and tomatoes is beneficial for enhancing immunity and treating vitamin A deficiency but is not effective for treating anemia due to its insufficient levels of iron, copper, vitamin C, and folate, which are essential for addressing anemia.

Table 6. The amount of vitamin C, iron, copper, and folate in the fresh drink made from different recipes.

	Fresh drink			
	Vitamin C (mg/100ml drink)	Fe mg/100ml drink	Cu mg/100ml drink	Folate µg/100ml drink
R1	3.88^{e}	0.36^{a}	0.085^{d}	2.94^{a}
R2	4.05^{d}	0.34^{b}	0.093^{c}	2.78^{b}
R3	4.13^{c}	0.32^{c}	0.097^{b}	2.70^{c}
R4	4.22^{b}	0.31^{c}	0.101^{b}	2.62^{d}
R5	4.39^{a}	0.28^{d}	0.109^{a}	2.46^{e}

$^{a-b}$ Means with distinct superscript alphabets in each column are substantially different between treatments

Evaluation of pH and acidity of recipes over storage periods

This study estimated the pH and acidity levels in five beverage recipes over a six-month storage period. The results indicated a decrease in pH and an increase in acidity over time. The rise in acidity and decline in pH during storage may be due to pectin hydrolysis or glycolysis. Ahmad et al. (2019) observed a similar trend in peach juices preserved for 90 days. Recipes R2 and R3 showed the smallest increase in acidity during storage, which positively impacted the taste and aroma of the drinks. R2 stood out as the best, as its flavor and color closely resembled that of an apricot drink. In contrast, the acidity increased significantly in the other recipes, especially in R5 and R4.

Evaluation of Total phenol (mg/100g) and Antioxidant activity % of recipes over storage periods

Figure 2 shows the levels of total phenols and antioxidant activity in various beverage recipes. The figure illustrates that the greater the amount of carrots used in the recipes, such as in R1, the higher the concentration of phenolic compounds in the drink. R1 had the highest phenol concentration, followed by R2, both at the beginning and end of storage. The results also show that as the proportion of sweet potatoes in the recipe increases at the expense of carrots, the phenolic content decreases. This was observed in R5, which had the highest percentage of sweet potatoes and the lowest phenolic content at both the start and end of storage. Over time, the phenolic compound content in all five recipes generally declined. Regarding antioxidant activity, R2 and R3 exhibited the highest levels both before and after storage. At the end of storage, R1 showed the lowest antioxidant activity, following R4 and R5. The reduction in total phenols and antioxidant activity during storage may be attributed to the condensation of polyphenols into brown pigments. These findings are consistent with those of Sharma et al. (2019) for the apple-whey beverage.

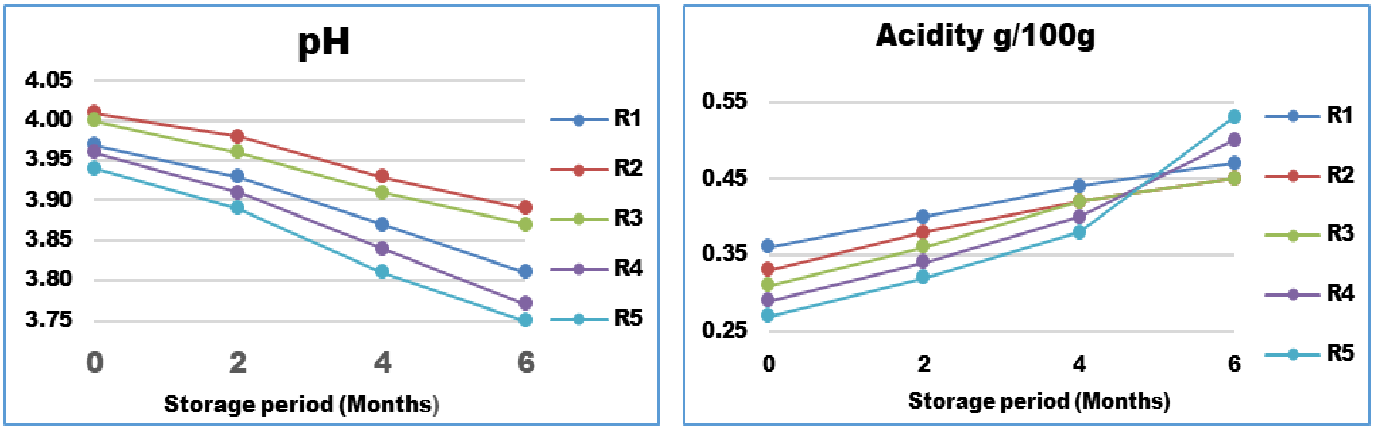

Figure 1. Evaluation of pH and acidity of recipes over storage periods

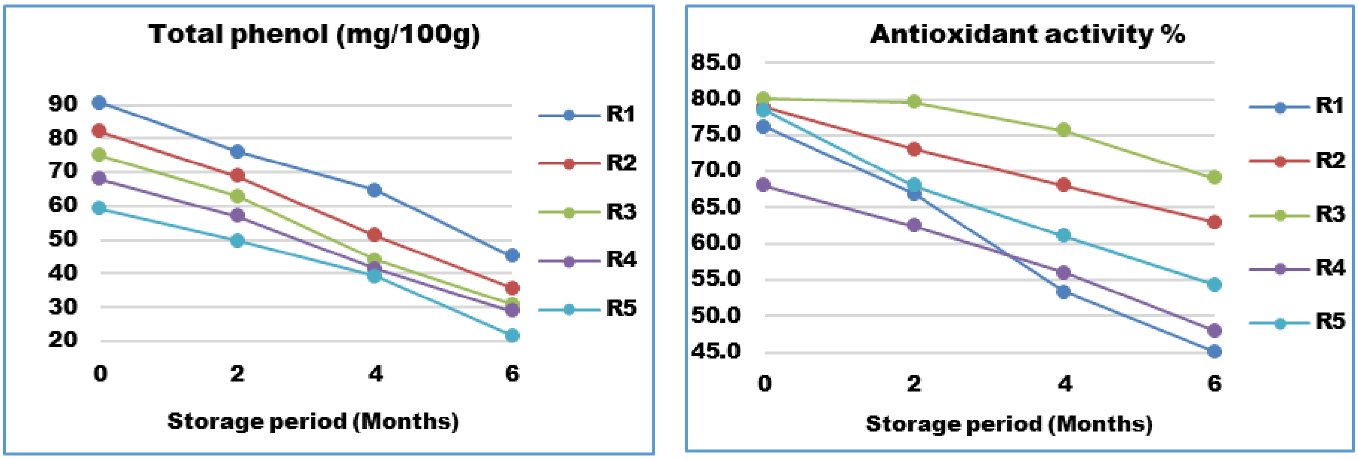

Figure 2. Evaluation of Total phenol (mg/100g) and Antioxidant activity % of recipes over storage

Evaluation of Alcohol soluble color and L* of recipes over storage periods

Figure 3 compares the five beverage recipes in terms of browning and transparency over a six-month storage period at room temperature. At the beginning of storage, the browning rates for the five recipes ranged from 0.070 to 0.090. After six months, browning increased to a range of 0.150 to 0.190, with growth rates between 0.081 and 0.100. The changes in browning during storage are primarily attributed to non-enzymatic browning or phenol oxidation, leading to increased browning, as noted by Bhardwaj and Mukherjee (2011) for kinnow juice, and Adeogun et al. (2017) for sweet orange juice. Mokhtar and Ibrahim (2020) also reported a similar increase in the browning index of guava nectar after six months of storage at room temperature. The recipes with the highest proportion of sweet potatoes showed the most browning by the end of storage, particularly R5 (0.190) and R4 (0.175), while R2 had the lowest browning (0.150), followed by R3 and then R1. These results align with the transparency (L*) values, where R2 exhibited the highest transparency (and the lowest browning), followed by R3 after six months of storage.

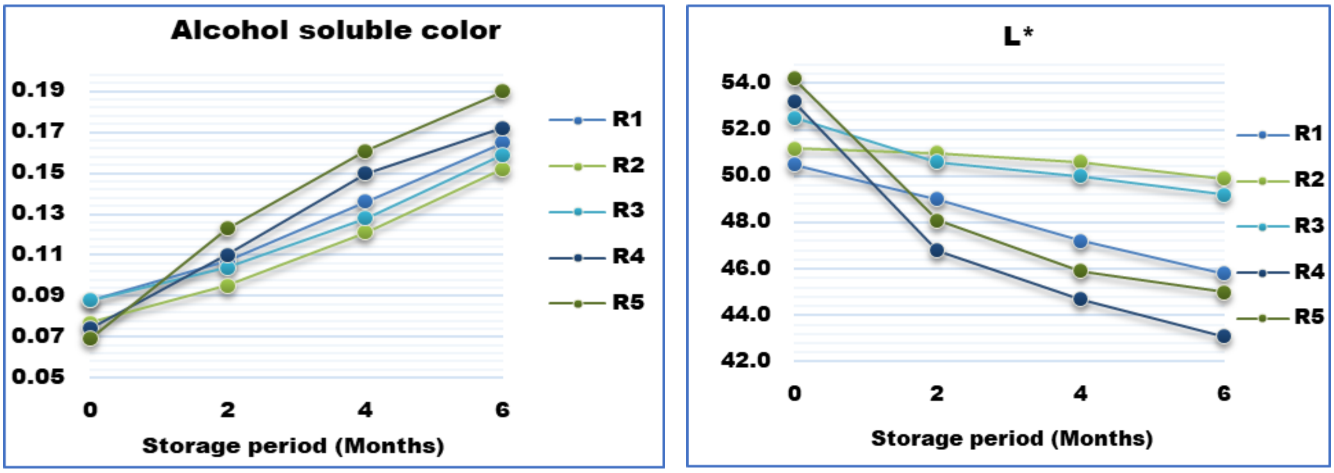

Figure 3. Evaluation of Alcohol soluble color and L* of recipes over storage periods

Evaluation of a* and b* of recipes over storage periods

The values of a* and b*, which are displayed in Figure 4, reveal how the red and orange hue of lycopene and carotenoid pigments decreases during storage. The degree of redness, as indicated by the value of a*, decreased during the period of six months of storage. At the conclusion of storage, recipes R2 and R3 showed the highest values, indicating a high level of redness in each of them and the retention of the lycopene pigment. However, the redness levels of recipes R5 and R4 were the lowest, which was mirrored in a drop in lycopene. Using the b* index, the same outcomes were seen, with recipes R2 and R3 having the highest levels of yellowing at the conclusion of storage and R5 and R4 having the lowest levels. Overall, the chemical data summary reveals that the R2 and R3 recipes have superior chemical properties to the other recipes, with R2 outperforming them all. The results shows that recipe R2 had the highest level of β-carotene and vitamin A equivalent units at the end of storage. 100 ml of this recipe meets daily vitamin A equivalent requirements for all groups except pregnant and breastfeeding women. They must take 200 ml per day of this R2 recipe or any other recipe to meet their daily needs. The chemical analysis of the drinks prepared from the various recipes revealed that R5 and R4 had the lowest chemical features.

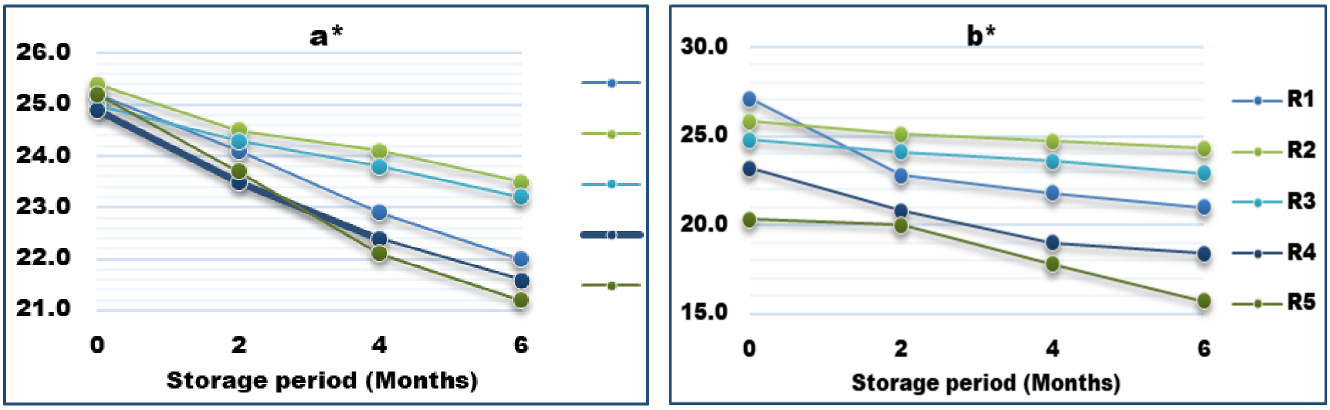

Figure 4. Evaluation of a* and b* of recipes over storage periods.

Microbiological Analysis

Microbiological examination of processed and stored recipe samples revealed bacterial, yeast, and mold counts below 10 CFU/mL (data not shown). The acquired findings met the requirements of Egyptian nectar standards, EOS No. 1602-1/2005. Thus, the various recipes were deemed safe for ingestion due to their minimal microbial burden. This might be attributed to the heat pasteurization (85° C/25 seconds) and low pH values (3.75-4.00) of the tested recipes. Silva et al. (2016) for red guava juice reported similar findings after 6 months of storage at ambient temperature.

Sensory evaluation of recipes over the storage periods

Table 5 presents the sensory attributes of the proposed beverage recipes. The findings at the beginning of storage indicate that a higher ratio of carrots to sweet potatoes in the formula correlates with greater overall acceptability of the drink. R1 had the highest overall acceptability score at the start, followed by R2, R3, R4, and R5. The scores ranged from 8.0 to 8.5, with a difference of approximately 0.5 points between recipes. At the end of storage, R2 achieved the highest overall acceptability score (8.1), followed by R3 (7.9), R1 (7.7), R4 (7.3), and R5 (7.1), with a 1.0-point difference between the highest (R2) and lowest (R5) scores.

Factors such as transparency (L*), redness (a*), yellowness (b*), total phenols, antioxidant activity, pH, and β-carotene levels all influenced overall acceptability. Increasing these factors generally produced the most favorable results. By the end of storage, recipes with lower transparency, redness, and yellowness scores exhibited a notable decline in average overall acceptability. Similar trends were observed in the storage of various juice types by Ibrahim and Khashaba (2020).

In summary, R2 outperformed the other recipes in terms of taste, smell, color, mouthfeel, appearance, and overall acceptability. These findings are consistent with the results of chemical and physical analyses, confirming R2's superiority. It is therefore recommended for addressing or preventing vitamin A deficiency by consuming 100 ml of the drink daily, which would meet the body's required daily intake of vitamin A for all age groups, except pregnant and lactating women, who should consume 200 ml of R2 to ensure sufficient vitamin A intake, particularly for vegetarians. However, the findings also show that these recipes do not meet the daily requirements for vitamin C, iron, copper, and folate, making them unsuitable for treating or reducing the risk of anemia.

Table 7. Sensory evaluation of recipes over the storage periods

	Sensory evaluation											
	At zero time						After storage					
	Taste	Odor	Color	Mouth Feel	Appear-ance	Overall Accepta-bility	Taste	Odor	Color	Mouth Feel	Appear-ance	Overall Accepta-bility
R1	8.6^a	8.6^a	8.6^a	8.6^a	8.1^a	8.5^a	7.7^c	7.3^c	8.1^c	7.4^c	7.8^c	7.7^c
R2	8.6^a	8.6^a	8.6^a	8.1^b	8.1^a	8.4^b	8.3^a	7.8^a	8.3^a	7.8^a	8.3^a	8.1^a
R3	8.6^a	8.1^b	8.6^a	8.1^b	8.1^a	8.3^c	8.1^b	7.5^b	8.2^b	7.6^b	8.0^b	7.9^b
R4	8.1^b	7.9^c	8.6^a	7.8^c	7.8^b	8.0^d	7.3^d	7.0^d	7.8^d	7.0^d	7.6^d	7.3^d
R5	8.1^b	7.8^d	8.6^a	7.6^d	7.8^b	8.0^d	7.0^e	6.8^e	7.6^e	6.5^e	7.4^e	7.1^e

$^{a-b}$ Means with distinct superscript alphabets in each column are substantially different between treatments

4.Conclusion

In conclusion, the significance of vitamin A precursors, such as β-carotene—found in vegetables like carrots, sweet potatoes, and tomatoes—cannot be overstated. These foods play a crucial role in treating vitamin A deficiency, alleviating anemia symptoms, and protecting against many non-communicable diseases by boosting immunity. Using ingredients rich in vitamin A precursors and other essential nutrients to develop food products offers a natural solution to combat vitamin deficiencies and anemia without the side effects associated with medications or supplements. These products maintain high biological value due to their natural composition. This approach presents a promising strategy for addressing malnutrition, population growth, and other global challenges, particularly in low-income and developing nations, while striving to improve nutritional outcomes. By leveraging the inherent nutritional and functional benefits of these vegetables, such solutions can provide social, therapeutic, and economic benefits to vulnerable populations.

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