Formulation of carrot juice enriched with chia seeds and cinnamon and evaluation on body composition

Lashkr Hamid Hamza[a*], Halgord Ali Farag[a]

[a] Food Science and Quality Control, Halabja Technical College, Sulaimani Polytechnic University, Sulaymaniyah, Iraq

. lashkrdolbeshki@gmail.com _ halgord.farag@spu.edu.iq

Abstract

Today, overweight is considered one of the most important health problems worldwide. In spite of a reliable and successful drug/s for obesity control, a phytonutrient-rich syrup made from carrot juice, chia seeds, and cinnamon was tested for its effects on overweight and body composition. Herbal syrups have acquired popularity in modern therapy due to their possible health advantages, specifically as alternative treatments for a variety of diseases.

This study aimed to evaluate the physicochemical composition, mineral composition and effects of consuming a functional beverage consisting of carrot syrup enriched with chia seeds and cinnamon on various metabolic health parameters. An eight-week randomized controlled trial was conducted and the experimental group (CCC: carrot-chia-cinnamon syrup) was compared with the placebo group. Key results showed favorable physicochemical characteristics and significant effects on body weight, muscle mass, body fat percentage, BMI and total body water content. The CCC group showed significant improvements in muscle mass, body fat percentage and water content. The findings of this study indicate that this functional beverage has the potential to have health-promoting effects on body composition and hydration status.

Keywords: Metabolic syndrome, Carrots, Chia seeds, Cinnamon, Health benefits

1. Introduction

Metabolic syndrome (Mets) is one of the most important global health problems, affecting approximately 30% of the world's population and is predicted to reach more than 50% in the next two decade[1]. Characterized by criteria such as abdominal obesity, impaired glucose tolerance, hypertension, and dyslipidemia, this syndrome imposes heavy economic and social costs on societies[2].

In Iraq, the results of the World Health Organization (WHO) reports in 2018 showed that the prevalence of obesity in adolescents aged 13 to 18 was 7.9% and overweight was 25.3%[3]. In Iraqi Kurdistan, a 2015 study showed that the prevalence of Mets in the study sample was 30.6%, with women more affected by this health problem than men[4]. A study conducted by Kamal et al. in the Kirkuk region showed that Mets is very common in type 2 diabetic patients in this region, especially in women and people with high BMI [5]. A study conducted in Sulaymaniyah

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in 2024 showed that Mets is very common in obese patients, especially in women, with 67% of female participants and 33% of male participants suffering from Mets[6].

In the present era, rapid lifestyle changes resulting from urbanization and industrialization have made paying attention to healthy nutritional patterns an inevitable necessity [7] and The use of natural diets and herbal medicines has attracted widespread attention due to the desire to consume non-toxic foods and minimize the adverse effects of chemicals[8-10]. Dietary factors, particularly deficiencies of bioactive plant micronutrients (phytonutrients), strongly contribute to the pathogenesis and progression of metabolic disorders. As a result, there is a growing scientific and consumer-driven demand for accessible, palatable, and natural functional foods designed to modulate metabolic pathways and reduce associated risks[11].

Carrots *(Daucus carota L.)* and carrot juice are known as one of the main and natural sources of carotenoids (especially beta-carotene, a precursor of vitamin A), polyphenols and dietary fiber, which play a significant role in strengthening the immune system and neutralizing free radicals. Studies have shown that phenolic compounds in carrots, such as chlorogenic acid, can help reduce inflammation and improve lipid profiles and lipid metabolism, and are associated with improved insulin sensitivity[12, 13]. For example, daily consumption of carrot juice for 8 weeks significantly reduced oxidative stress markers in overweight individuals[14].

Cinnamon (*Cinnamomum verum*), which is valued for its distinctive flavor and medicinal properties, has also been shown to have significant effects on improving insulin sensitivity with active compounds such as cinnamaldehyde. It can help regulate glucose metabolism by activating the AMPK pathway, increasing glucose uptake and improving insulin signaling. In addition, it has significant antioxidant capacity[15, 16] . According to a meta-analysis that included 10 clinical trials, daily cinnamon consumption was able to reduce fasting blood sugar levels by an average of 20 mg/dL [17].

Chia seeds (*Salvia hispanica L.*) have anti-inflammatory and lipid profile-improving effects due to their high content of omega-3 fatty acids, alpha-linolenic acid (ALA), and soluble fiber (mainly mucilage), high-quality protein, and minerals. These components have shown promise in regulating postprandial glycemia, increasing satiety, and improving lipid profiles[18, 19]. Studies have report that regular consumption of chia seeds can reduce waist circumference and increase blood HDL levels. In a clinical study, consuming 35 grams of chia seeds per day for 3 months led to significant improvements in metabolic markers in people with Mets[20].

The combination of these three ingredients can have significant synergistic effects. In this regard, the antioxidants in carrots, along with the blood sugar-lowering compounds in cinnamon and the soluble fiber in chia seeds, could be considered an effective way to manage weight and improve metabolic indicators. However, limited studies have evaluated the combined effects of these compounds, indicating the need for further research in this area. Given that a large population in the Middle East is struggling with overweight, the need for applied research in the field of prevention and treatment strategies is more evident than ever. Currently,

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common treatments in this field are mainly focused on lifestyle modification and chemical drugs, but the attention and use of natural compounds and medicinal plants can be investigated due to fewer side effects and cost-effectiveness. This study was conducted to evaluate the effect of consuming a combination of carrot juice containing chia seeds and cinnamon as natural sources on Mets and health index.

2. Materials and Methods

2.1 Materials

2.1.1. Preparing the raw ingredients for the syrup made from carrot juice, chia seeds, and cinnamon powder

All natural raw materials used in this study were purchased from reputable local vendors and evaluated and verified to ensure the quality and reliability of the products. Analytical grade chemicals and reagents used in chemical profiling were purchased from Sigma-Aldrich (St. Louis, MO, USA).

2.1.2. Steps to prepare syrup made from carrot juice, chia seeds, and cinnamon powder

Fresh carrot juice was extracted with a juicer. To smooth the texture of the syrup, we filtered the juice to remove any pulp. We mixed the carrot juice and water in a large bowl and gradually added the thickeners maltodextrin, xanthan gum, and guar gum, stirring constantly to prevent lumps. We mixed the syrup until it reached the desired viscosity. Next, we added the hydrated raw chia seeds (left for 30 minutes to absorb water and swell) and mixed well to evenly distribute them. Add the cinnamon powder and mix thoroughly until smooth. Honey was used as a natural sweetener and preservative in the mixture. Citric acid and vitamin C were added to the mixture and stirred well to ensure even distribution, and the pH was adjusted to stabilize the mixture. The syrup was then heated to 70-75°C for 10-15 minutes, then cooled rapidly. This step can help increase shelf life, but was done carefully to preserve nutrients. BPA-free glass or plastic bottles were filled with the syrup while it was still warm. The bottle caps were tightly closed and stored in a dry place at low temperature until use.

Carrot juice, chia seeds, and cinnamon powder (CCC syrup) were prepared based on the following ingredients:

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Table 1. ingredients of Placebo (PLA) syrup and Carrot Juice Syrup with Cinnamon and Chia Seeds (CCC syrup)

Ingredients	PLA (placebo)	CCC syrup
Carrot Juice	0	50%
Raw Chia Seeds	0	5%
Cinnamon Powder	0	2%
Honey	0	10%
Corn Syrup	20%	0
Maltodextrin	5%	5%
Xanthan Gum	0.3%	0.3%
Guar Gum	0.3%	0.3%
Citric Acid	0.2%	0.2%
Vitamin C	0	0.1%
Water	70%	27.1%
Flavoring Agent	0.5%	0
Natural Food Coloring	To match the color of the active syrup (e.g., beta-carotene or a food-safe orange dye)	0

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2.2. Methods

2.2.1. Measurement Methods physicochemical properties

In this study, the physicochemical properties of the syrup were measured by standard methods. pH was determined using a calibrated digital pH meter. Soluble solids (°Brix) were calculated using a handheld refractometer and titratable acidity was calculated using a titration method using 0.1 normal sodium hydroxide. Viscosity was measured using a Brookfield viscometer at constant speed and temperature. Specific gravity was measured using a pycnometer and turbidity was measured using a turbidimeter. Color parameters (L*, a*, b*) were evaluated using a colorimeter in the CIE Lab system. Electrical conductivity was determined using a digital conductometer and ascorbic acid content was determined using an iodometric method. Reducing sugars and total sugars were measured using DNS and phenol-sulfuric acid methods, respectively.

2.2.2. Mineral Measurement

The elemental and mineral composition of the syrup containing carrot juice, chia seeds, and cinnamon was measured and analyzed using an inductively coupled plasma emission spectrometer (ICP-OES, model PerkinElmer Optima 8300, made in the United States)

2.2.3. Participants

This study was conducted as a randomized controlled trial (RCT) with a pretest-posttest design with a control group. In this study, the effect of carrot juice containing chia seeds and cinnamon on body mass indices was investigated.

In this randomized clinical trial, 65 individuals with symptoms of Mets between the ages of 18 and 45 (both sexes) were studied for 2 months (8 weeks). 10 of the selected individuals withdrew from the trial due to factors (illness, pregnancy), and studies were conducted on 55 individuals.

According to the NCEP ATP III definition presented in 2001, only three of the five criteria listed below are positive for the diagnosis of this syndrome[21]:

Waist circumference (WC)>102 cm in men and WC>89 cm in women,

High blood pressure (systolic blood pressure ≥ 130 mmHg or diastolic blood pressure ≥ 85 mmHg or current or previous high blood pressure or history of high blood pressure,

Fasting blood sugar (FBS) ≥ 100 mg/dL or taking medication. Increased blood sugar (TG>150 mg/dL)

Or increased blood lipids (HDL<50 mg/dL) in women and HDL<40 mg/dL in men)

In all individuals, Mets was considered.

During the intervention period (8 weeks), all patients in both groups were followed up. Weekly telephone calls were made to participants in both groups to ensure adherence to the intervention and to inform them of any side effects of consuming carrot juice containing cinnamon and chia seeds. To increase participant cooperation, an educational pamphlet was first provided to

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both groups, including lifestyle conditions and risk factors for diabetes, high cholesterol, blood pressure, fatty liver, oxidative stress, overweight and obesity, how to diagnose, control and treat them, and the role of daily physical activity, diet and antioxidants in reducing the risk of the aforementioned diseases. The content of the educational pamphlets was prepared and approved by experts. Anthropometric measurements and clinical tests were performed for all patients in both groups before and after eight weeks (Figure 1).

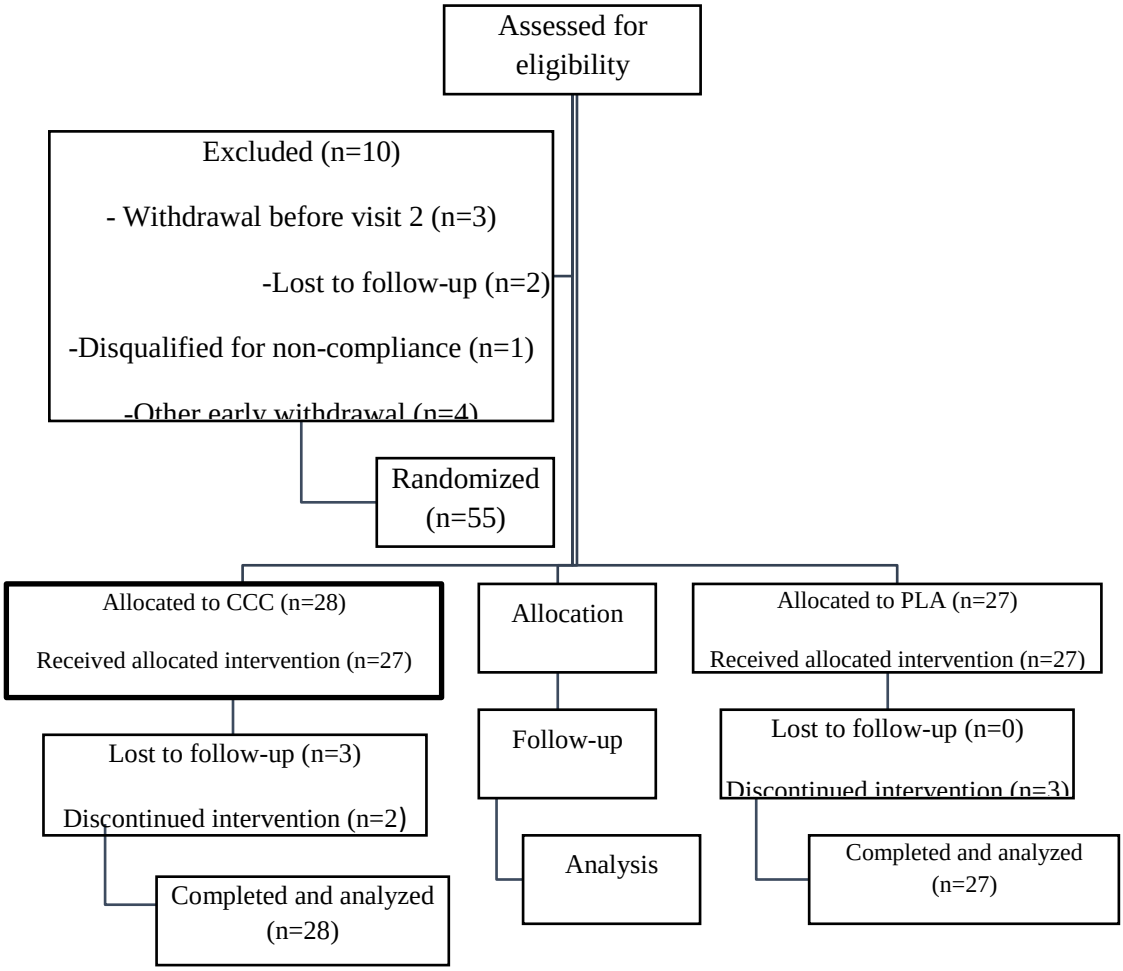

Figure 1 – Precipitation flow chart.

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2.1.4. Statistical analysis

Independent t-test was used to compare the mean of quantitative indicators between the two groups and the difference in the mean before and after these indicators in the two groups was used. The significance level in the study was considered to be 5%. The data were analyzed using SPSS ver.31 software.

3. Results

3.1. physicochemical properties and mineral of syrup made from carrot juice, chia seeds, and cinnamon powder

3.1 .1. physicochemical properties

According to the results of physicochemical analyses of the syrup prepared from carrot juice, chia seeds, and cinnamon, the characteristics of this colloidal system were determined (Table 2). In terms of parameters, pH was measured to be 3.8 and titratable acidity was 0.28% (based on citric acid), indicating an acid profile suitable for inhibiting the growth of pathogenic microorganisms. The total soluble solids (TSS) content was determined to be 11.20°Brix, which was the optimum concentration for the formation of the desired structure.

Also, rheological studies showed that the syrup had a non-Newtonian fluid behavior with an apparent viscosity of 12.5 mPa.s at a shear rate of 50 s-1. The specific gravity was 1.045 and the refractive index was 1.348 at 20°C. Colorimetric analysis using the CIE L*a*b* method showed values of 62.3 (L*), 14.1 (a*) and 42.5 (b*), indicating a yellow-orange color (b*>a*) with medium brightness.

Compositional analyses showed that the syrup contained 18.7 mg/100mL ascorbic acid (vitamin C) and 0.41% total ash. The soluble carbohydrate content included 9.3 g/100mL reducing sugars and 6.4 g/100mL total sugars. Themacromolecular composition included 0.9 g/100mL protein and 0.3 g/100mL total fat.

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Table2. physicochemical properties of Syrup with Raw Chia Seeds, Fine Powdered Cinnamon Carrot Juice

Parameter	Value	Unit
pH	3.8	
Total Soluble Solids (TSS, °Brix)	11.2	°Brix
Titratable Acidity (% citric acid)	0.28	%
Viscosity (mPa·s)	12.5	mPa·s
Specific Gravity	1.045	
Turbidity (NTU)	75	NTU
Color (L*)	62.3	L*
Color (a*)	14.1	a*
Color (b*)	42.5	b*
Electrical Conductivity (µS/cm)	1120	µS/cm
Ascorbic Acid (Vitamin C, mg/100mL)	18.7	mg/100mL
Reducing Sugars (g/100mL)	6.4	g/100mL
Total Sugars (g/100mL)	9.3	g/100mL
Ash Content (%, dry basis)	0.41	%
Moisture Content (%)	89.8	%
Total Carbohydrates (g/100mL)	9.5	g/100mL
Protein Content (g/100mL)	0.9	g/100mL
Fat Content (g/100mL)	0.3	g/100mL

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3.1.2. Mineral composition

ICP-MS analysis showed that the syrup contained significant levels of essential electrolytes, with potassium (673.21 ppm) identified as the most abundant element, which plays a significant role in regulating osmotic pressure and enzyme activity. Calcium (421.17 ppm) and magnesium (150.13 ppm) provided 21.42% and 38.55% of the Recommended Daily Intake (RDI), respectively, which are important in bone metabolism and neuromuscular function. Among the trace elements, iron (18.31 ppm) and zinc (6.85 ppm) cover 22.89% and 85.63% of the RDI, respectively, which play a vital role in hematopoietic processes and immune system function. Copper (0.84 ppm) has also been identified to be present in the structure and activity of enzymes with antioxidant roles, such as superoxide dismutase. Notably, the levels of potentially toxic elements were low, with lead (1.01 ppm) below the Codex Alimentarius limit (2 ppm) and other heavy elements including cadmium, arsenic and mercury at undetectable levels (<0.1 ppm), confirming the safety of product consumption (Table 3).

Table 3. Mineral composition of Syrup with Raw Chia Seeds, Fine Powdered Cinnamon, and Carrot Juice (CCC syrup)

Mineral (ppm)	Carrot syrup (CCC)	Mineral (ppm)	Carrot syrup (CCC)
Ag	<0.1	Mo	<0.1
Al	3.1	Na	467.25
As	<0.1	Nd	<0.1
B	0.14	Ni	<0.1
Ba	0.25	P	316.14
Be	<0.1	Pb	1.01
Bi	0.17	Pd	<0.1
Ca	421.17	Pr	<0.1
Cd	<0.1	Pt	<0.1
Ce	<0.1	Rh	<0.1
Co	<0.1	S	350.12
Cr	<0.1	Sb	<0.1

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Cu	0.84	Sc	<0.1
Dy	<0.1	Se	<0.1
Er	<0.1	Sm	<0.1
Eu	<0.1	Sn	<0.1
Fe	18.31	Sr	0.75
Ga	<0.1	Tb	<0.1
Gd	<0.1	Te	<0.1
Ge	<0.1	Th	<0.1
Hf	<0.1	Ti	<0.1
Hg	<0.1	Tl	<0.1
Ho	<0.1	Tm	<0.1
Ir	<0.1	U	<0.1
K	673.21	V	<0.1
La	<0.1	W	<0.1
Li	<0.1	Y	<0.1
Lu	<0.1	Yb	<0.1
Mg	150.13	Zn	6.85
Mn	0.75	Zr	<0.1

Values marked "<0.1" indicated concentrations below the detection limit.

3.2. Anthropometric Measures

3.2.1. The effect of consuming carrot syrup containing chia seeds and cinnamon on weight

The results of the statistical analysis showed that at baseline, the mean weight in the placebo group (PLA) was 85.41 ± 14.72 kg and in the intervention group (CCC syrup) was 86.99 ± 13.12 kg, with no statistically significant difference between the two groups (p=0.676). After the intervention period, the weight of the placebo group increased to 86.10 ± 13.12 kg, while the syrup group showed a weight loss of 84.45 ± 12.32 kg. Although

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these changes did not reach a statistically significant level (p=0.610), the decreasing trend observed in the CCC group is significant (Table 4 and 5) (Figure 2, A).

3.2.2. The effect of consuming carrot syrup containing chia seeds and cinnamon on muscle mass

According to the results presented in Tables 4 and 5, at baseline, the mean muscle mass in the placebo group (PLA) was 12.41 ± 1.06% and in the intervention group (CCC syrup) was 12.54 ± 0.98%, with no significant difference between the two groups (p=0.987). After the intervention period, while the placebo group experienced a slight decrease in muscle mass (12.30 ± 1.3%), the group consuming carrot juice, chia seeds, and cinnamon showed a significant increase in muscle mass (13.18 ± 1.1%, p=0.0001) (Figure 2, B).

3.2.3. The effect of consuming carrot syrup containing chia seeds and cinnamon on body fat

As shown in Tables 4 and 5, at baseline, the mean body fat percentage in the control group (PLA) was 31.07 ± 8.63% and in the intervention group (CCC syrup) was 29.64 ± 9.13% (p=0.540). After the intervention period, while the control group showed an increase in body fat percentage (32.40 ± 8.3%), the syrup consuming group experienced a significant decrease in this index (26.6 ± 6.8%), which was statistically highly significant (p=0.0025) (Figure 2, C).

3.2.4. The effect of consuming carrot syrup containing chia seeds and cinnamon on BMI

According to the results presented in Tables 4 and 5, at baseline, the two groups were completely homogeneous in terms of BMI (PLA: 31.58 ± 5.67 kg/m²; CCC syrup: 31.46 ± 4.52 kg/m²; p=0.892). After the intervention period, while the placebo group demonstrate a slight increase in BMI (31.9 ± 5.1 kg/m²), the syrup group experienced a significant decrease (30.1 ± 3.8 kg/m²). Although this change did not reach the statistical significance threshold (p=0.054), it is clinically important, as it represents a 4.3% decrease from baseline (figure 2, D).

3.2.5. The effect of consuming carrot syrup containing chia seeds and cinnamon on body water content

The results of the study show a significant effect of consuming carrot juice, chia seeds, and cinnamon syrup on the body's hydration status (Tables 4 and 5). At baseline, the percentage of body water in the placebo group (PLA) was measured as 42.15 ± 5.92% and in the intervention group (CCC syrup) as 47.61 ± 6.37%, with a statistically significant difference between the groups (p=0.0016). After 8 weeks of intervention, while the

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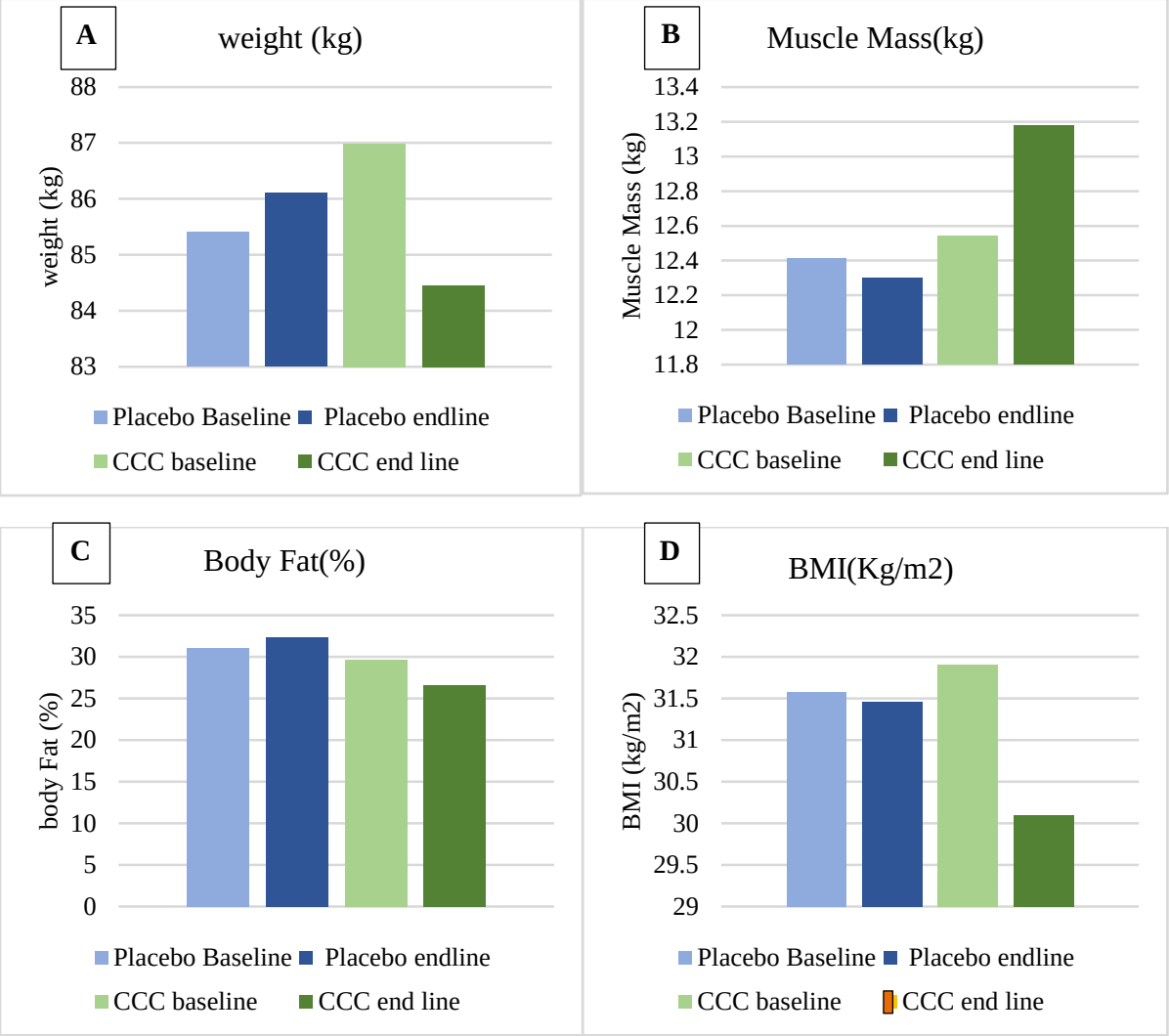
placebo group showed a slight decrease in water percentage (41.1 ± 5.4%), the syrup consuming group experienced a significant increase (49.4 ± 5.9%), with this difference body

also being statistically significant (p=0.0001) (Figure 2, E).



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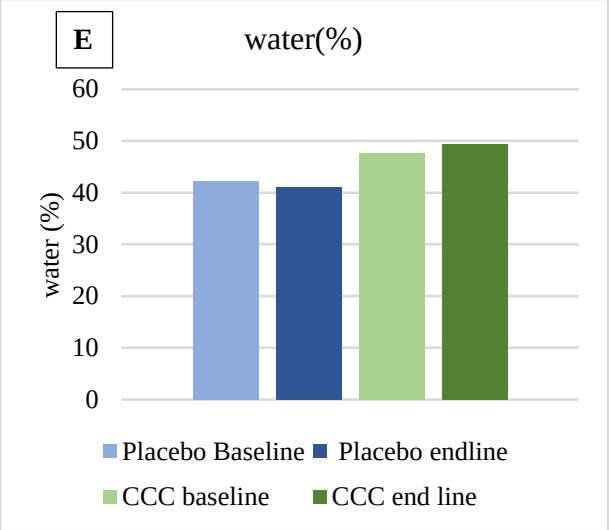

Figure 2. Anthropometric changes after 8 weeks of intervention with carrot syrup containing chia seeds and cinnamon (CCC syrup, n=28, green bars) and placebo (PLA, n= 27, blue bars). Light colors indicate baseline; dark colors indicate endline. Data are mean ± SEM. Statistical differences by one-way ANCOVA adjusted for baseline.

Table4- Participant baseline demographics

variable	PLA (mean ± SD)	CCC (mean ± SD)	P value	Cohen ‘s d
Participants(n)	27	28	-	
Gender (M/F)	15/12	15/13		
weight	85.41±14.72	86.99 ± 13.12	0.676	011
Muscle mass	12.41± 1.06%	12.54 ± 0.98%	0.987	0.1
Body fat	31.07 ±8.63%	29.64 ±9.13%	0.540	0.17
BMI	31.58±5.67	31.46 ± 4.52	0.892	0.02
Water	42.15±5.92%	47.61 ± 6.37%	0.0016	0.89

Data presented as Mean ± SD. BMI: body mass index. SEM: standard error of the mean.

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Table5.post-8-weeks. Anthropometric Measures (Mean ± SD) and Between-Group Comparisons

variable	PLA (mean ± SD)	CCC (mean ± SD)	P value
weight	86.10 ±13.12	84.45 ±12.32	0.610
Muscle Mass	12.30 ± 1.3%	13.18 ± 1.1%	0.0001***
Body Fat	32.40 ± 8.3%	26.6 ± 6.8%	0.0025*
BMI	31.9 ± 5.1	30.1 ± 3.8	0.054
Water	41.1 ± 5.4%	49.4 ± 5.9%	0.0001***

Data ara presented as Mean ± SD. Between-group p-value were calculated using ANCOVA. Adjusted for baseline values. BMI: body mass index. PLA: Placebo. CCC: carrot syrup containing chia seeds and cinnamon. Coupled t-test compared within groups. *; $p<0.05$, **; $p \leq 0.01$, ***; ≤ 0.001. within -group comparison.

4. Discussion

carrots (Daucus carota L.), chia seeds (Salvia hispanica L.), and Cinnamon (Cinnamomum spp.), are three plant materials with a rich profile of bioactive compounds and have been widely studied for their beneficial effects on metabolic health and body composition. Carrots, as one of the most widely consumed vegetables, are a rich source of beta-carotene (provitamin A), vitamins C and E, and carotenoids, which, as strong antioxidants, play a role in reducing oxidative stress (a major factor in the development of Mets), strengthening the immune system, and preventing chronic diseases including cancer and cardiovascular diseases [22, 23]. Chia seeds also play an important role as a functional food due to their omega-3 fatty acids (especially alpha-linolenic), soluble fiber, high-quality protein, and phenolic compounds such as rosmarinic and caffeic acids, which play an effective role in lowering cholesterol, regulating glycemic levels, and improving intestinal function. In addition, their antioxidant and anti-inflammatory properties make them an effective ingredient in the prevention of cardiovascular diseases, diabetes, and neurological disorders[24, 25]. Cinnamon, as a spice rich in polyphenols and volatile compounds such as cinnamaldehyde, has antioxidant, anti-inflammatory, antimicrobial, and hypoglycemic properties and is known to be effective in the management of metabolic diseases including type 2 diabetes and lipid disorders[26-28]

The results of this study showed that regular consumption of syrup made from carrot juice, chia seeds and cinnamon for 8 weeks had positive and significant effects on body composition indices. This natural formulation with favorable physicochemical properties, including acidic pH (3.8), soluble solids content (11.2 °Brix) and ideal viscosity (12.5 mPa.s), has high potential as a beverage with functional food applications. Low pH and appropriate vitamin C content can help increase the shelf life of the product, while the

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balanced content of sugars and the presence of functional ingredients such as chia seeds and cinnamon increase the nutritional value of the product. The measured rheological properties also indicate the appropriate consistency and favorable sensory acceptability of the product.

Clinically, the most important finding of this study was the simultaneous improvement of several body composition indicators, including increased muscle mass, decreased body fat, and improved hydration status.

Although no significant difference was observed between the placebo and intervention groups, carrot juice, chia seed, and cinnamon syrup reduced the weight of the intervention group (p=0.610). Consumption of carrot juice, chia seeds, and cinnamon can be considered as an effective weight management strategy. This combination affects weight loss through multiple biochemical and physiological mechanisms. Carrot juice, as a rich source of beta-carotene and dietary fiber, reduces adipocyte differentiation by modulating the activity of PPAR-γ receptors[29].Also, the soluble fiber in carrots stimulates the exudation of satiety hormones such as GLP-1 by increasing the production of short-chain fatty acids (SCFAs) in the intestine[30, 31]. Obia et al. [32]. Consumption of carrot aqueous extract at medium doses (200 and 400 mg/kg) resulted in a significant increase in body weight by 24.65% and 27.49%, respectively, while this increase in the group receiving the high dose (600 mg/kg) was similar to the control group (21.3%).on other hand Mahesh et al. [33] reported that daily consumption of carrot juice (50 ml, equivalent to 2400 micrograms of beta-carotene) for 6 weeks led to a significant reduction in body weight in diabetic patients. Chia seeds play an important role in this combination. These seeds, with their high levels of soluble fiber, form a hydrogel upon contact with water, which, by increasing volume in the stomach, stimulates stretch receptors and the secretion of satiety hormones such as cholecystokinin (CCK) and peptide YY[34]. Also, the omega-3 fatty acids in chia seeds increase the thermogenesis process and energy consumption by increasing the expression of the UCP-1 protein in brown adipose tissue[35]. Cinnamon, as the third component of this compound, contains cinnamaldehyde, which reduces the absorption of sugar and fat by inhibiting the digestive enzymes α-glucosidase and lipase[36]. Also, the polyphenolic compounds of cinnamon increase the oxidation of fatty acids and reduce lipogenesis by activating the AMPK pathway[37]. This compound is also effective in weight control by reducing TNF-α levels and improving leptin sensitivity[38].

The significant increase in muscle mass (p=0.0001) is likely due to the synergistic effects of high-quality chia seed protein [39] and the improvement of insulin sensitivity by cinnamon polyphenolic compounds [40]. The combination of carrot juice, chia seeds, and cinnamon has significant synergistic effects on muscle health and performance. This combination improves muscle protein synthesis, reduces muscle breakdown, and accelerates post-exercise recovery through several biochemical mechanisms. As a rich source of plant protein (about 23%) and essential amino acids such as leucine, chia seeds play a key role in stimulating the mTOR pathway and muscle protein synthesis[41]. In addition, omega-3 fatty acids in chia seeds (especially ALA) prevents inflammation-induced muscle loss by reducing the

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emanation of pro-inflammatory factors such as TNF-α and IL-6[36, 42, 43].

Carrot juice, containing antioxidant compounds such as beta-carotene and polyacetylenes, reduces oxidative stress in muscle tissue caused by exercise[44]. These compounds prevent damage to muscle cell membranes and mitochondria by neutralizing free radicals produced during muscle metabolism. Also, the potassium in carrot juice (about 320 mg/100 g) plays a role in regulating muscle contractions and preventing cramps caused by electrolyte deficiency [45].

Cinnamon, with its active compounds, especially cinnamaldehyde, has a significant effect on muscle function. These compounds improve glucose uptake into muscle cells by increasing insulin sensitivity and increasing muscle glycogen storage[36]. Cinnamon also prevents the destruction of muscle proteins by inhibiting protein-degrading enzymes such as calpain and caspase-3[46]. Studies have shown that cinnamon polyphenolic compounds increase the expression of muscle growth factors such as IGF-1[47]. This finding is consistent with the results of a study by Ziegenfus et al.[48], who showed that cinnamon consumption resulted in a 1.1% increase in lean mass. Also, a study by Zare et al. [49]also confirmed the positive effects of cinnamon on anthropometric indices. Nieman et al. [50]also reported that consuming 25 grams of chia seeds per day for 12 weeks improved hydration status and reduced inflammation. These factors may help preserve muscle mass.

The significant reduction in body fat percentage (p=0.0025) could be related to multiple mechanisms, including inhibition of fat absorption by chia seed fiber [50]and increased fatty acid oxidation by cinnamon active compounds[36]. Mahesh et al. [33] in their human study, they demonstrated that daily consumption of carrot juice (50 ml, equivalent to 2400 micrograms of beta-carotene) for 6 weeks led to a significant reduction in body fat percentage in diabetic people.

Although no significant difference was observed between the placebo and intervention groups in terms of BMI, carrot juice, chia seeds, and cinnamon syrup reduced the body mass index of the intervention group (p=0.054). This finding is consistent with the results of a meta-analysis including five studies with 369 participants, which showed that cinnamon can reduce BMI by 0.31 units[51]. However, some studies, such as Vafa et al. [52] and Akilen et al. [53], did not report a significant change in BMI. Also, Namazi et al. [17] reported in a clinical study that cinnamon consumption did not cause any statistically significant changes in BMI, waist circumference, or body weight of participants. This finding is consistent with the results of a meta-analysis study by Jamali et al.[54], which indicated that cinnamon had no significant effect on body composition, which may be due to differences in dose, duration of intervention, or demographic characteristics of the subjects studied.

Notably, in the intervention group, increase in body water percentage (p=0.0001) was observed, which can be attributed to the high ability of chia seeds to absorb and retain water (up to 12 times its dry weight)[50] and the effect of natural electrolytes in vegetable like carrots on body fluid balance[55]. This finding is of particular clinical importance, as proper hydration plays a key role in metabolic

functions, body temperature regulation, and muscle performance.

Carrot juice, as the basis of this drink, in addition to providing water to the body, contains important electrolytes such as potassium, which play a vital role in osmotic balance and maintaining extracellular fluid volume[45]. The potassium present in carrots (about 320 mg/100 g) together with the natural sodium present in chia seeds, creates a balanced electrolyte environment that is essential for optimal water absorption in the intestine[56]. Studies have shown that beverages containing natural electrolytes provide more sustained hydration than pure water[57].Cinnamon in this blend affects fluid balance through several mechanisms. The active compounds in cinnamon, particularly cinnamaldehyde, help regulate sodium and water balance in the body by modulating antidiuretic hormone (ADH) secretion and improving insulin sensitivity[36]. Cinnamon also regulates capillary permeability by improving endothelial function and preventing edema caused by capillary leak[40].

Overall, the combination of carrot juice, chia seeds, and cinnamon can be considered an effective strategy for weight management and improving body composition. This combination affects weight loss, muscle mass gain, and hydration status through multiple biochemical and physiological mechanisms. However, more detailed studies are needed to determine the optimal dose and investigate the long-term effects of this combination. These findings could provide a basis for introducing new functional food products in the management of Mets and improving overall health.

5. Conclusion

The present study demonstrated that 8 weeks of consumption of a combination syrup containing carrot juice, chia seeds, and cinnamon powder can lead to significant improvements in body composition through multiple mechanisms. This formulation, by combining natural bioactive compounds, has high potential for clinical applications in weight management and body composition improvement and has several key advantages, including natural origin of active ingredients, favorable safety profile, good physicochemical stability, and multifactorial effects on metabolic health. Overall, the findings of this study indicate that a combination syrup containing carrot juice, chia seeds, and cinnamon can be considered as a natural and safe supplement option in body composition modification and weight management programs. By combining the benefits of all three ingredients, this formulation produces significant synergistic effects on body composition indices, and improved hydration status. Given its high safety, reasonable cost, and easy availability of raw materials, this functional beverage has broad potential applications in the fields of functional nutrition and public health.

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