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Assessing Biochemical Composition of Citrus Juice and its Health Impact in Hypertensive Adults

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Abstract

The nutritional composition of citrus juice was evaluated, and its potential health effects were investigated through a controlled, small-scale human intervention study. Participants meeting predefined inclusion criteria consumed citrus juice over several weeks, during which changes in key health parameters were monitored. Citrus juice intake did not significantly affect blood glucose levels or diastolic blood pressure. However, notable improvements were observed in systolic blood pressure, triglyceride concentrations, and both LDL and HDL cholesterol levels. Minor reductions in LDL cholesterol and triglycerides were also recorded, though these may have been influenced by dietary variations among participants. A modest decrease in body weight was observed, suggesting that weight loss is more closely linked to overall dietary habits than to citrus juice consumption alone. Overall, the findings suggest that incorporating citrus juice into the diet may support improved lipid profiles and contribute to cardiovascular health.

1. Introduction

The prevalence of hypercholesterolemia is rising at an alarming rate, currently affecting nearly 45 million adults in the United States. Similarly, findings from the Second National Diabetes Survey of Pakistan (NDSP, 2016-2017) reported that approximately 39.3% of adults aged 20 years and above exhibited hypercholesterolemia, as indicated by elevated total cholesterol levels (Basit *et al.*, 2020). This condition is associated with various adverse health outcomes, including myocardial infarction, cerebrovascular accidents, and heart failure. To mitigate these significant risks, individuals need to monitor their blood pressure and maintain optimal cholesterol levels. Clinical guidelines frequently advocate for dietary modifications alongside pharmacological interventions. Globally, the medical community is increasingly recognizing the gravity of this public health issue. Nevertheless, a lack of awareness regarding the potential severity of hypercholesterolemia's consequences persists among the general population, thereby complicating efforts to prevent its detrimental effects (Verma *et al.*, 2021).

The incidence and prevalence of hyperlipidemia remain considerably high, with estimates from claims data slightly exceeding those reported in official statistics. In Germany, approximately one in five individuals is affected by the condition. Although the precise causes of mortality among

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patients with hyperlipidemia are not fully understood, evidence indicates that mortality rates in this population are elevated and appear to be rising. With the progressive aging of the German population, the healthcare burden associated with hyperlipidemia is expected to increase substantially in the coming years (Mevius *et al.*, 2024).

Among citrus fruits, oranges have the highest production rates about 60% of the total citrus world production (Park *et al.*, 2014). Orange (*Citrus sinensis*) is a member of the citrus family Rutaceae. Citrus fruits and their juices contain a diverse array of bioactive compounds. The antioxidant properties and associated health benefits are attributed not only to vitamin C but also to other phytochemicals, particularly flavonoids (Martí *et al.*, 2009). The orange occupies a prominent position in the human diet. It is derived from an ancient hybrid, primarily believed to originate from mandarin (*Citrus reticulata*) and pomelo (*Citrus maxima*) species (Hazarika *et al.*, 2014). Historically, citrus pulp has been widely utilized as an appetizer, antitoxic agent, stomach tonic, and cardiac tonic (Duarte *et al.*, 2016). Flavonoids constitute a key component of its biochemical profile, with naringenin, neo hesperidin, and hesperidin being the principal flavonoids found in substantial quantities within pomelo pulp and juice.

According to the National Center for Health Statistics (2011), many individuals include orange juice in their diets to support balanced nutrition, primarily because it is a rich source of vitamin C. This aligns with the findings of Newberry and Brennan (2013), who reported that health-conscious consumers frequently select orange juice for the same reason. More broadly, fruits and vegetables are vital components of a healthy diet as they provide phytochemicals, dietary fiber, and essential micronutrients that contribute to disease prevention. These plant-derived compounds, including antioxidants and other bioactive substances, have been associated with reduced risk of chronic illnesses, highlighting the importance of promoting fruit and vegetable consumption for maintaining overall health (González *et al.*, 2015).

2. METHODOLOGY

2.1. Chemical Composition

Moisture content and ash content of citrus juice were carried through McCleary *et al.* (2013). Crude fiber and ascorbic acid were estimated. Antioxidant potential and total phenolic content were determined by method involving Folin-Ciocalteu reagent and Gallic acid as the standard (Motamed *et al.*, 2016).

2.2. Physiochemical Analysis

PH and acidity content were measured by using the method of Ben-Gigirey *et al.*, (2012)

2.3. Study Design

Forty (40) hypertensive patients were selected of age 34-62 years and divided into two groups. Each group comprised 20 subjects and was assigned to receive 250ml/day citrus juice and at the same time 250ml/day water between lunch and dinner time.

2.4. Serum Lipid Profile

Blood pressure was measured at both baseline and at the end of study using a standardized clinical procedure. Serum cholesterol levels were determined using the CHOD-PAP method, as described by Qadir *et al.* (2011), while triglyceride concentrations were assessed with the GPO-PAP method for liquid triglycerides, following the protocol of Fadhilah *et al.* (2019). High-density lipoprotein (HDL) cholesterol was analyzed using the HDL Cholesterol Precipitant method, and low-density lipoprotein (LDL) cholesterol was calculated according Rutering *et al.* (2014).

2.5. Statistical Analysis

The data obtained from different parameters were statistically analyzed for significance using analysis of variance (ANOVA) as outlined by Montgomery (2020).

3. Results

The citrus juice contained 86.04% water and 0.327% ash. Dietary fiber, primarily composed of the edible parts of plants such as parenchyma tissues, plays a vital role in human health by aiding digestion and reducing the risk of chronic diseases, particularly cardiovascular disorders. The crude fiber content of the juice was 34.5%. Antioxidant activity, measured through DPPH radical scavenging, was 48.0%, while the total phenolic content was 641 µg per mL (Table 1).

The pH of the citrus juice was 4.07, indicating moderate acidity. Over time, an increase in acidity results in a decrease in pH. Acidity, measured at 0.40% (Table 2), is important not only for flavor enhancement but also for inhibiting the growth of harmful microorganisms, thereby extending shelf life. In terms of physiological effects, consumption of citrus juice did not significantly alter blood glucose levels or diastolic blood pressure. However, notable improvements were observed in systolic blood pressure, total cholesterol, and triglyceride levels. Additionally, citrus juice intake led to an increase in high-density lipoprotein (HDL) and a decrease in low-density lipoprotein (LDL) levels, indicating a positive impact on lipid profile (Table 3).

Table 1. Nutritional composition of citrus juice on a dry weight basis, including moisture, ash content, crude fiber, phenolic compounds, vitamin C, and antioxidant activity.

Parameters	Values
Moisture	86.04%
Ash content	0.327%
Crude fiber	34.5%
Total Phenolic contents	641µg/ml GAE
Vitamin C	560.8 µg/Ml
DPPH	48.0%.

Table 2. Physicochemical characteristics of citrus juice, including pH and titratable acidity

Parameter	Values
PH	4.07
Acidity	0.40 %

The analysis demonstrated that daily citrus juice consumption produced significant improvements in several cardiovascular and lipid parameters, while others remained largely unaffected. Systolic blood pressure showed a highly significant reduction in the citrus juice group compared to the placebo group as shown in Figure 1. Moreover, the time and group interaction indicated that this reduction was both more pronounced and sustained among individuals consuming citrus juice. In contrast, diastolic blood pressure exhibited no major differences between groups overall. However, significant week-to-week variation and a notable time and group interaction were observed, suggesting that fluctuations may have been influenced by additional factors beyond the intervention. Blood glucose levels remained stable throughout the study, with no significant differences between groups or across time, indicating that citrus juice intake neither improved nor worsened glycemic control in the study population. Total cholesterol and triglyceride levels decreased markedly in the citrus juice group, with reductions sustained across the study period (Figure 2).

High-density lipoprotein (HDL) cholesterol increased significantly as shown in Figure 3, reflecting an improvement in protective lipids, while low-density lipoprotein (LDL) cholesterol decreased, lowering cardiovascular risk (Figure 4). In contrast, very low-density lipoprotein (VLDL) cholesterol showed minimal variation, suggesting that the metabolic effects of citrus juice may preferentially target specific lipid fractions. Collectively, these findings indicate that regular citrus juice intake may be a valuable dietary strategy for improving systolic blood pressure and enhancing lipid profiles in hypertensive adults, without exerting measurable effects on blood glucose regulation.

4. Discussion

Roberts and Gaddum (1936) reported moisture contents of 87.35% in seedling orange juice, 87.85% in blood orange juice, 88.20% in Valencia orange juice, and 87.40% in legit gong orange juice. Eyduran *et al.* (2015) analyzed organic acids, phenolics, sugars, and antioxidant capacity of orange juice and wine, finding an ash content of 3.7 g/L. Similarly, Muramatsu *et al.* (2010) evaluated orange juice and reported 0.3% ash content. Pasquet *et al.* (2010), in a study on rheological characterization of food thickeners for dysphagia management, reported dietary fiber levels in orange juice of <1.0 g/100 mL, while Muramatsu *et al.* (2010) observed 0.1% fiber content.

The antioxidant capacity of orange juice has been reported in several studies. Romeo *et al.* (2020) recorded 49.2% antioxidant activity via DPPH during their investigation of storage effects on orange juice. Hossam *et al.* (2018) found an antioxidant potential of 156.83 mL/g while examining refrigeration effects on vitamin C and antioxidant stability. Kelebek *et al.* (2020) measured a DPPH value of 0.31 mL/mg in fresh orange juice while assessing organic acids, sugars, phenols, and antioxidant levels. Betoret *et al.* (2012) reported 2.8% DPPH activity in orange juice in their study on homogenization during juice processing. Roussos (2011) found 36.8% DPPH activity and highlighted the influence of organic versus conventional farming systems on phytochemicals and antioxidant potential.

Studies on total phenolic content (TPC) also show wide variability. Van Bavel *et al.* (2012) reported TPC of 755 µg per mL GAE while investigating the synergistic roles of vitamin C, phenols, and carotenoids in antioxidant enhancement of fruit juices. Modica *et al.* (2024) measured TPC values of 55.4 and 28.0 for Moro and Sanguinello orange juices, respectively. Roussos (2011) reported 964 mg/L TPC when comparing organic and conventional farming practices. Guimaraes *et al.* (2010) studied various citrus species (grapefruit, lemon, and orange), reporting a TPC of 12.41 mg GAE/g in orange juice.

Regarding physicochemical properties, Pendlebury and Rothwell (2019) found a pH of 4.28 in orange juice while studying the effects of high-pressure treatment on chemical, physical, and microbiological characteristics. Bernabé and Plaza (2011) reported a lower pH of 3.51 in freshly squeezed juice and an acidity of 0.79%, focusing on refrigeration effects on vitamin C content and antioxidant capacity.

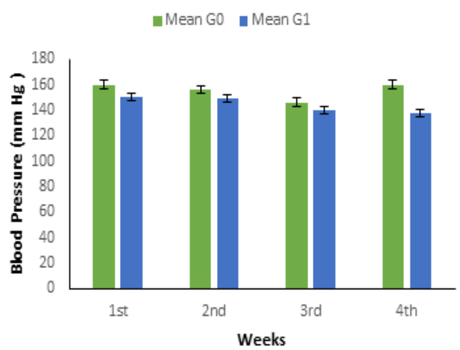

Figure 1. Weekly changes in systolic blood pressure between the citrus juice and control groups.

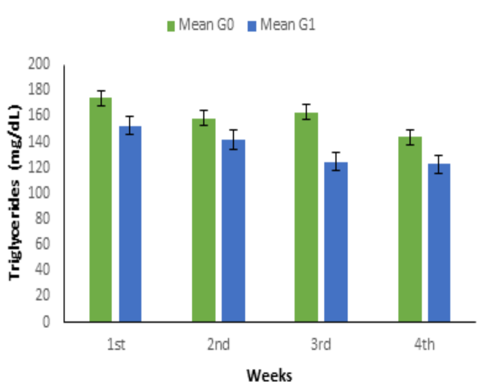

Figure 2. Variation in triglyceride levels across four weeks in both study groups.

Beyond compositional studies, citrus juice has demonstrated positive effects on lipid metabolism. Wilund et al. (2013) observed that pomegranate juice consumption significantly reduced LDL oxidation and carotid artery stenosis. Trovato (2012) reported that hypercholesterolemic rats given *Citrus sinensis* and Citrus limon for 15 days showed a 49% reduction in total cholesterol and a 51% decrease in triglycerides. Similarly, Aptekmann and Cesar (2013) observed total cholesterol reductions of up to 44% and 48% in rabbits fed citrus juices. HDL levels improved markedly: in rats fed C. sinensis, HDL rose from 5.2 mg (control) to 22.9 mg after 15 days, while C. limon showed a smaller effect. Conversely, C. limon proved more effective in lowering LDL, with a 50% reduction compared to C. sinensis. Additional studies demonstrated that orange and grapefruit juices reduced LDL cholesterol by 43% and 32%, respectively.

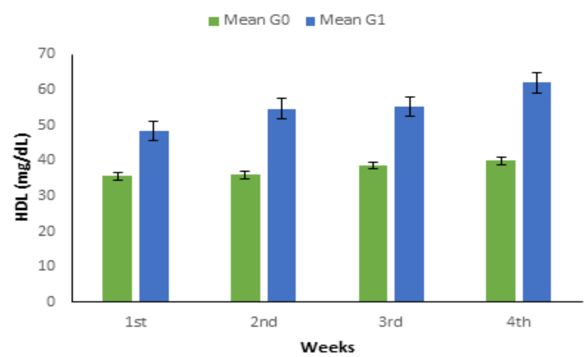

Figure 3. Changes in HDL cholesterol levels during the study period.

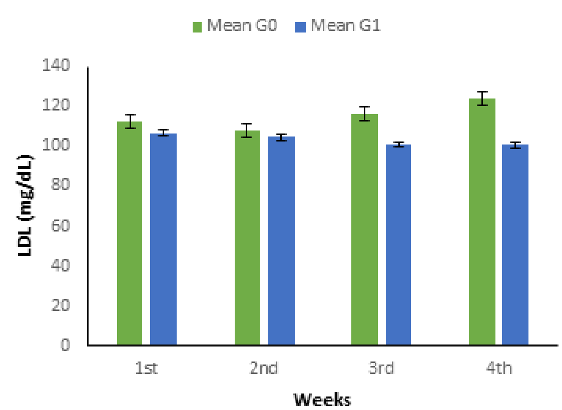

Figure 4. LDL cholesterol trends in participants following daily citrus juice intake

Table 3. Summary of variance analysis (ANOVA) showing the effect of citrus juice consumption on selected physiological and biochemical parameters.

	SOV	DF	SS	MS	F Value
Systolic blood pressure	**Groups**	1	770.67	770.667	243.37**
	Weeks	3	237.83	79.278	25.04**
	G×W	3	531.33	177.111	55.93**
	Error	16	50.67	3.167	
	Total	23	1590.50		
Diastolic blood pressure	**Groups**	1	4.167	4.167	0.47ns
	Weeks	3	327.000	109.000	12.28**
	G × W	3	128.833	42.944	4.84*
	Error	16	142.000	8.875	
	Total	23	602.000		
Blood glucose level	**Groups**	1	504.17	504.167	10.86ns
	Weeks	3	91.00	30.333	0.65ns
	G × W	3	108.17	36.056	0.78ns
	Error	16	742.67	46.417	
	Total	23	1446.00		
Cholesterol level	**Groups**	1	1617.04	1517.04	121.28**
	Weeks	3	372.13	124.04	9.30**
	G × W	3	495.46	165.15	12.39**
	Error	16	213.33	13.33	
	Total	23	2697.96		
Triglycerides level	**Groups**	1	3577.04	3577.04	205.87**
	Weeks	3	2857.46	952.49	54.82**
	G × W	3	426.46	142.15	8.18**
	Error	16	278.00	17.37	
	Total	23	7138.96		
High-density lipo-protein	**Groups**	1	1837.50	1837.50	77.50**
	Weeks	3	252.00	84.00	3.54*
	G × W	3	68.50	22.83	0.96*
	Error	16	379.33	23.71	
	Total	23	2537.33		
Low-density lipo-protein	**Groups**	1	864.00	864.000	35.09**
	Weeks	3	116.83	38.944	1.58*
	G × W	3	393.67	131.222	5.33**
	Error	16	394.00	24.625	
	Total	23	1768.50		
Very low-density lipoprotein	**Groups**	1	12.042	12.0417	0.88*
	Weeks	3	4.792	1.5972	0.12*
	G × W	3	19.792	6.5972	0.48*
	Error	16	219.333	13.7083	
	Total	23	255.958		

Where ** means highly significant, * means significant while ns means non-significant at α=0.05

Table 4. Weekly mean values showing the impact of citrus juice on blood pressure, blood glucose, and lipid profile among study participants.

	Weeks	Groups		Mean
		G_0	G_1	
Systolic blood pressure	**1st**	160.00 a	150.33 c	155.17 a
	2nd	156.00 b	139.67 e	147.83 b
	3rd	146.00 d	149.00 cd	147.50 b
	4th	159.67 a	137.33 e	146.40 b
	Mean	155.42 a	144.08 b	
Diastolic blood pressure	**1st**	82.000 c	81.333 c	81.667 bc
	2nd	90.667 a	86.333 abc	88.500 a
	3rd	75.333 d	82.000 c	78.667 c
	4th	87.667 ab	81.667 bc	85.167 ab
	Mean	83.917 a	82.083 a	
Blood glucose level	**1st**	96.667 a	80.667 bc	88.667 a
	2nd	92.333 ab	86.000 abc	89.167 a
	3rd	88.000 abc	83.000 bc	85.500 a
	4th	89.333 abc	80.000 c	84.667 a
	Means	91.583 a	82.417 b	
Cholesterol level	**1st**	187.33 ab	177.67 cd	182.50 a
	2nd	181.33 bc	172.00 d	176.67 b
	3rd	179.00 c	164.00 e	171.50 c
	4th	190.33 a	155.67 e	170.50 c
	Mean	184.75 a	168.33 b	
Triglyceride level	**1st**	174.00 a	152.67 c	163.33 a
	2nd	158.67 bc	142.00 d	150.33 b
	3rd	163.33 b	124.6 e	144.00 c
	4th	143.67 d	122.67 e	133.17 d
	Mean	159.92 a	135.50 b	
High-density lipo-protein	**1st**	35.667 d	48.333 bc	42.000 b
	2nd	36.000 d	54.667 ab	45.333 ab
	3rd	38.667 d	55.333 ab	47.000 ab
	4th	40.000 cd	62.000 a	51.000 a
	Mean	37.583 b	55.083 a	
Low-density lipo-protein	**1st**	112.33 bc	106.67 cd	109.50 ab
	2nd	108.00 bcd	104.67 cd	106.33 b
	3rd	116.33 ab	101.00 d	108.67 ab
	4th	124.33 a	100.67 d	112.50 a
	Mean	115.25 a	103.25 b	
Very low-density lipoprotein	**1st**	28.667 a	25.334 e	27.000 a
	2nd	28.000 b	25.000 e	26.500 b
	3rd	27.000 c	26.667 d	26.833 b
	4th	25.333 a	26.333 dc	25.833 c
	Mean	27.250 a	25.833 b	

Where G_0 = Control group G_1 = Female group

5. Funding

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7. Conflict of Interest

The authors declare no conflict of interest.

8. Authors' Contribution

Javeria Safder was responsible for data collection, experimental work, and initial drafting of the manuscript. Faiza and Asma Arooj Ramzan contributed to data analysis, interpretation of results, and preparation of figures/tables. Anas Shakoor assisted in, referencing, and proofreading. All authors read and approved the final version of the manuscript.

9. SDGs Addressed

This study supports SDG 3 (Good Health and Well-being) by promoting dietary strategies for managing hypertension and cardiovascular health, and aligns with SDG 12 (Responsible Consumption and Production) by encouraging the use of natural, nutrient-rich foods for sustainable health improvement.

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