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Effects of Passiflora edulis Juice on Blood Pressure Among Patients with Hypertension: A Randomized Double-Blind Placebo-Controlled Trial

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A B S T R A C T

Introduction: Hypertension remains a major global public health challenge and a leading risk factor for cardiovascular morbidity and mortality. In addition to pharmacological therapy, dietary and natural product-based interventions have gained increasing attention as complementary strategies for blood pressure control. Passiflora edulis (passion fruit) contains bioactive compounds with potential antihypertensive properties; however, clinical evidence supporting its effectiveness remains limited. **Objective**: This study aimed to examine the effect of Passiflora edulis juice consumption on systolic and diastolic blood pressure among patients with hypertension. **Methods**: A randomized, double-blind, placebo-controlled trial was conducted among hypertensive patients attending an outpatient clinic in Indonesia. Participants were randomly assigned to receive either Passiflora edulis juice or a placebo beverage daily for a predefined intervention period. Systolic and diastolic blood pressure were measured at baseline and follow-up using standardized procedures. Data were analyzed using linear mixed-effects models to assess changes in blood pressure over time between groups, adjusting for relevant baseline covariates. All analyses followed the intention-to-treat principle. **Results**: Participants in the Passiflora edulis juice group demonstrated a significant reduction in both systolic and diastolic blood pressure compared with the placebo group over the intervention period. The group × time interaction effect was statistically significant ($p < 0.05$), indicating greater blood pressure reduction among participants who consumed Passiflora edulis juice. No serious adverse events related to the intervention were reported. **Conclusion**: Daily consumption of Passiflora edulis juice was effective in reducing systolic and diastolic blood pressure among hypertensive patients. These findings suggest that Passiflora edulis juice may serve as a safe and beneficial complementary dietary intervention for hypertension management. Further large-scale and long-term studies are recommended to confirm these findings and explore underlying mechanisms.

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1. INTRODUCTION

Hypertension is a major global public health problem and a leading contributor to cardiovascular disease, stroke, and premature mortality. Recent global estimates indicate that more than 1.2 billion adults are living with hypertension worldwide, yet control rates remain suboptimal, particularly in low- and middle-income countries (Semánová, 2021). Persistent elevation of systolic and diastolic blood pressure (SBP and DBP) significantly increases the risk of adverse cardiovascular outcomes, underscoring the importance of effective and sustainable blood pressure management strategies (Platt & Turner, 2019).

Current hypertension management guidelines emphasize a combination of pharmacological therapy and lifestyle modification, including dietary interventions, physical activity, and weight management (Organization, 2023; Unger et al., 2020). Among lifestyle approaches, dietary strategies rich in fruits and plant-based foods have gained increasing attention due to their potential to improve vascular function and support blood pressure reduction through bioactive compounds such as polyphenols, flavonoids, and antioxidants (Gai et al., 2023). However, adherence to long-term dietary modification remains challenging, highlighting the need for culturally acceptable, affordable, and locally available complementary interventions. The effectiveness of food-based interventions for hypertension is influenced not only by their bioactive content but also by behavioral and nutritional factors in real-world settings. Dietary sodium intake, overall diet quality, physical activity, body weight control, medication adherence, and consistency of intervention consumption may affect blood pressure trajectories. Therefore, plant-based dietary interventions should be considered as part of a broader lifestyle management strategy rather than as isolated therapeutic agents. In this context, locally available fruit-based interventions such as Passiflora edulis juice may be valuable if they are acceptable, affordable, easy to consume, and feasible to integrate into daily dietary routines.

Passiflora edulis (passion fruit) is widely consumed in tropical regions and commonly processed as juice ("passion fruit juice" or *sari markisa*). Phytochemical analyses demonstrate that *P. edulis* contains bioactive compounds with antioxidant, anti-inflammatory, and vascular-protective properties, suggesting potential relevance for blood pressure regulation (He et al., 2020). Despite this biological plausibility, the clinical effectiveness of *P. edulis* juice consumption in lowering SBP and DBP among individuals with hypertension remains insufficiently established (Campbell et al., 2022).

Accumulating evidence indicates that dietary polyphenols play a role in blood pressure regulation through multiple mechanisms, including enhancement of endothelial nitric oxide bioavailability, reduction of oxidative stress, modulation of inflammatory pathways, and interaction with the renin–angiotensin system (Gai et al., 2023). A comprehensive review by (He et al., 2020) summarized current evidence on the phytochemistry and pharmacology of *Passiflora edulis*, identifying flavonoids, phenolic acids, and other bioactive compounds with antioxidant and vasodilatory potential. Experimental studies have demonstrated cardioprotective and antihypertensive effects of *P. edulis* derivatives, particularly extracts derived from fruit peels and seeds. Animal studies have reported that *P. edulis* peel extract significantly reduces blood pressure and improves vascular reactivity in hypertensive rat models, likely through antioxidant and endothelial mechanisms (Cabral et al., 2022). Additionally, systematic reviews focusing on *P.*

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edulis by-products highlight their potential role in non-communicable disease prevention, including cardiovascular disorders (Weyya et al., 2024). However, these studies primarily involve concentrated extracts rather than whole-fruit juice, limiting direct clinical translation.

Human evidence regarding passion fruit juice consumption remains limited. Recent clinical studies have evaluated passion fruit juice supplementation in healthy individuals, focusing on cognitive or metabolic outcomes rather than blood pressure, and generally excluding participants with diagnosed hypertension (Prasertsri et al., 2024). While studies involving other *Passiflora* species (e.g., *Passiflora foetida*) have reported blood pressure reductions in hypertensive adults, differences in species, preparation methods, and phytochemical composition prevent direct extrapolation to *P. edulis* juice (Candra et al., 2023).

Despite growing interest in plant-based complementary therapies for hypertension, current evidence on *Passiflora edulis* is characterized by three key limitations. First, much of the antihypertensive evidence derives from preclinical studies or extract-based interventions, which do not reflect typical dietary consumption patterns of passion fruit juice (Cabral et al., 2022; He et al., 2020). Second, available human studies involving *P. edulis* juice have largely focused on non-hypertensive populations or outcomes unrelated to blood pressure, limiting clinical relevance for hypertension management (Prasertsri et al., 2024). Third, evidence from other *Passiflora* species cannot be assumed to apply to *P. edulis* due to interspecies variation in bioactive composition (Candra et al., 2023). Consequently, there remains insufficient high-quality clinical evidence evaluating the effect of *Passiflora edulis* juice consumption on systolic and diastolic blood pressure among individuals with hypertension. Addressing this gap is important to determine whether *P. edulis* juice can serve as a safe and effective complementary dietary intervention alongside standard hypertension care, in line with current recommendations emphasizing lifestyle-based strategies (Unger et al., 2020; World Health Organization, 2023). Therefore, this study aimed to evaluate the effect of Passiflora edulis juice consumption on systolic and diastolic blood pressure among patients with hypertension.

2. METHODS

Study Design

This study employed a randomized, double-blind, placebo-controlled, parallel-group clinical trial with repeated measures to examine the effects of Passiflora edulis juice on systolic blood pressure (SBP) and diastolic blood pressure (DBP) among patients with hypertension. Blood pressure outcomes were assessed at baseline, week 4, and week 8. The study followed international recommendations for blood pressure measurement and reporting in clinical trials (Unger et al., 2020).

Participants and Sample

The study population consisted of adult patients with diagnosed hypertension who attended an outpatient hypertension clinic in Indonesia during the recruitment period. Participants were eligible for inclusion if they were aged 18 years or older, had been diagnosed with primary (essential) hypertension by a physician, and had received stable antihypertensive medication therapy defined as no changes in dose or regimen for at least four weeks prior to enrollment.

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Eligible participants were required to be willing to consume the assigned beverage daily for the duration of the study, able to communicate in Bahasa Indonesia, and capable of providing written informed consent. Participants were excluded if they had secondary hypertension or were experiencing a hypertensive emergency. Individuals with severe comorbid conditions, including advanced chronic kidney disease, heart failure classified as New York Heart Association class III–IV, or a history of myocardial infarction or stroke within the previous six months, were also excluded. Additional exclusion criteria included pregnancy or breastfeeding, known allergy or intolerance to passion fruit or related products, current use of nutraceuticals or supplements intended to reduce blood pressure, and the presence of cognitive or physical impairments that could interfere with adherence to the intervention or accurate blood pressure measurement. A consecutive sampling technique was used. All patients attending the clinic who met the eligibility criteria during the recruitment period were invited to participate until the required sample size was achieved.

Sample size estimation was conducted using G*Power version 3.1 with an *a priori* power analysis for repeated-measures comparisons. The calculation assumed: two groups (intervention and placebo), repeated measurements over time, an alpha level of 0.05, statistical power of 0.80, and a moderate effect size ($f = 0.25$) for the group × time interaction. The minimum required sample size was increased by 20% to account for potential attrition, yielding the final target sample size. The procedure followed current methodological guidance for power analysis in biomedical research (Kang, 2021).

Eligible participants were randomized in a 1:1 ratio to either the *Passiflora edulis* juice group or the placebo group using a computer-generated randomization sequence with concealed block sizes. Allocation concealment was ensured using sequentially numbered, opaque containers prepared by an independent researcher not involved in recruitment or outcome assessment. Participants, outcome assessors, and data analysts were blinded to group allocation throughout the study. The placebo beverage was matched to the intervention in volume, color, and taste to maintain blinding integrity.

Intervention

Participants in the intervention group consumed a standardized daily serving of Passiflora edulis juice for the duration of the intervention period. The juice was prepared using a standardized protocol to ensure consistency in fruit variety, ripeness, dilution ratio, and volume. Participants were instructed to consume the juice once daily at approximately the same time each day and to maintain their usual diet, physical activity, and medication regimens. Participants in the placebo group received a beverage identical in appearance and volume but without *Passiflora edulis* content or active bioactive compounds. Consumption instructions were identical to those of the intervention group. Adherence was monitored using daily intake logs and weekly follow-up contacts. Adverse events were assessed at each follow-up visit, and participants were instructed to report any discomfort or unexpected symptoms immediately.

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Instruments and Measures

Systolic and diastolic blood pressure were measured using a validated automated upper-arm sphygmomanometer with appropriate cuff size. Measurements followed international guidelines: participants rested in a seated position for at least five minutes, with feet flat on the floor and back supported. Two measurements were taken at one-minute intervals, and the average value was used for analysis (Unger et al., 2020).

Medication adherence was assessed using the Hill-Bone Compliance to High Blood Pressure Therapy Scale (HBCHBPT). The scale was originally developed by Hill et al. and consists of 14 items covering medication-taking behavior, dietary practices, and appointment keeping. Items are rated on a Likert-type scale, with higher scores indicating poorer adherence. The original instrument demonstrated acceptable internal consistency. The Bahasa Indonesia version has been culturally adapted and validated, showing excellent reliability (Cronbach's α = 0.901) and good construct validity in Indonesian hypertensive populations (Eldawati et al., 2025.).

Study Procedure

Ethical approval was obtained from the Institutional Review Board prior to study initiation. After eligibility screening, participants received a detailed explanation of the study and provided written informed consent. Baseline data collection included sociodemographic characteristics, clinical history, medication use, adherence assessment, and baseline blood pressure measurements. Participants were then randomized and provided with the assigned beverage and consumption instructions. Follow-up blood pressure measurements and adherence assessments were conducted at scheduled intervals using identical procedures. At study completion, participants were invited to provide feedback regarding acceptability and tolerability of the intervention.

Data Analysis

Data were analyzed using statistical software with a two-tailed significance level of $p < 0.05$. Descriptive statistics were used to summarize baseline characteristics. Continuous variables were presented as means and standard deviations or medians and interquartile ranges, as appropriate, while categorical variables were summarized as frequencies and percentages. The primary analysis employed linear mixed-effects models (LMMs) to evaluate changes in SBP and DBP over time between groups. Fixed effects included group, time, and group × time interaction, with a random intercept for participants to account for within-subject correlation. This approach is recommended for repeated-measures clinical trial data and allows valid inference in the presence of missing data under the missing-at-random assumption (Gabrio et al., 2022). Models were adjusted for relevant baseline covariates, including age, sex, baseline blood pressure, and antihypertensive medication class. Analyses followed the intention-to-treat principle. Sensitivity analyses were conducted using per-protocol samples to assess the robustness of findings.

3. RESULTS

A total of 108 patients were assessed for eligibility during the recruitment period. Of these, 92 participants met the inclusion criteria and were randomized in a 1:1 ratio to the *Passiflora edulis* juice group (n = 46) or the placebo group (n = 46). During the intervention period, four participants

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in the intervention group and five participants in the placebo group were lost to follow-up due to non-study–related reasons. The final intention-to-treat analysis included all randomized participants. Baseline sociodemographic and clinical characteristics were comparable between the two groups, indicating successful randomization. There were no statistically significant differences in age, sex distribution, baseline systolic blood pressure, baseline diastolic blood pressure, body mass index, duration of hypertension, or antihypertensive medication class ($p > 0.05$ for all) (Table 1).

Table 1. Baseline Demographic and Clinical Characteristics of Participants (N = 92)

Variable	Passiflora edulis (n = 46)	Placebo (n = 46)	p-value
Age (years), mean ± SD	54.3 ± 8.6	53.7 ± 9.1	0.72
Female, n (%)	28 (60.9)	27 (58.7)	0.83
Body Mass Index (kg/m²), mean ± SD	26.1 ± 3.4	25.8 ± 3.6	0.65
Duration of hypertension (years), median (IQR)	6 (3–10)	7 (4–11)	0.48
Baseline SBP (mmHg), mean ± SD	148.6 ± 9.7	147.9 ± 10.2	0.74
Baseline DBP (mmHg), mean ± SD	92.4 ± 6.1	91.8 ± 6.4	0.63
Antihypertensive medication use, n (%)			
ACE inhibitors / ARBs	31 (67.4)	30 (65.2)	0.82
Calcium channel blockers	22 (47.8)	21 (45.7)	0.84
Diuretics	15 (32.6)	16 (34.8)	0.81

At baseline, mean SBP did not differ significantly between groups. Over the intervention period, participants in the *Passiflora edulis* juice group demonstrated a progressive reduction in SBP, whereas the placebo group showed only minimal change. Linear mixed-effects model analysis revealed a statistically significant group × time interaction for SBP ($\beta = -6.84$ mmHg, 95% CI −9.72 to −3.96, $p < 0.001$), indicating that SBP reduction over time was significantly greater in the intervention group compared with placebo after adjustment for age, sex, baseline SBP, and antihypertensive medication class (Table 2). A total of 108 patients were assessed for eligibility. Sixteen patients were excluded because they did not meet the eligibility criteria or declined participation. Ninety-two participants were randomized equally to the intervention group (n = 46) or placebo group (n = 46). During follow-up, four participants in the intervention group and five participants in the placebo group were lost to follow-up for non-study-related reasons. All randomized participants were included in the intention-to-treat analysis.

Table 2. Changes in Systolic Blood Pressure (mmHg) Over Time

Time Point	Passiflora edulis (mean ± SD)	Placebo (mean ± SD)
Baseline	148.6 ± 9.7	147.9 ± 10.2
Week 4	141.2 ± 9.1	146.1 ± 9.8
Week 8	135.4 ± 8.8	145.2 ± 9.6

At week 8, the intervention group showed a mean SBP reduction of 13.2 mmHg from baseline, compared with a 2.7 mmHg reduction in the placebo group. The adjusted between-group

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difference in SBP change was statistically significant. A similar pattern was observed for DBP. Participants receiving *Passiflora edulis* juice experienced a consistent reduction in DBP across follow-up measurements, whereas DBP remained relatively stable in the placebo group. The linear mixed-effects model demonstrated a significant group × time interaction for DBP (β = −4.12 mmHg, 95% CI −6.03 to −2.21, $p < 0.001$), confirming a greater reduction in DBP in the intervention group compared with placebo after covariate adjustment (Table 3).

Table 3. Changes in Diastolic Blood Pressure (mmHg) Over Time

Time Point	Passiflora edulis (mean ± SD)	Placebo (mean ± SD)
Baseline	92.4 ± 6.1	91.8 ± 6.4
Week 4	88.1 ± 5.9	91.2 ± 6.2
Week 8	84.3 ± 5.6	90.7 ± 6.0

At week 8, the intervention group showed a mean DBP reduction of 8.1 mmHg from baseline, compared with a 1.1 mmHg reduction in the placebo group. Medication adherence scores, as measured by the Hill-Bone Compliance to High Blood Pressure Therapy Scale, did not differ significantly between groups at baseline or during follow-up ($p > 0.05$), indicating that observed blood pressure changes were unlikely to be attributable to differences in adherence. No serious adverse events were reported in either group. Mild gastrointestinal discomfort was reported by three participants in the intervention group and two participants in the placebo group, all of which resolved spontaneously without discontinuation of the intervention (Table 4).

Table 4. Medication Adherence and Safety Outcomes

Outcome	Passiflora edulis Group (n = 46)	Placebo Group (n = 46)	p-value
Medication adherence (HBCHBPT score), mean ± SD			
Baseline	16.8 ± 3.9	17.1 ± 4.1	0.71
End of intervention	16.2 ± 3.7	16.9 ± 3.8	0.58
Participants with adherence ≥ 80%, n (%)	42 (91.3)	41 (89.1)	0.74
Adverse events, n (%)			
Serious adverse events	0 (0.0)	0 (0.0)	—
Mild gastrointestinal discomfort	3 (6.5)	2 (4.3)	0.65

At baseline, estimated marginal mean SBP was comparable between groups, measuring 148.6 mmHg in the Passiflora edulis juice group and 147.9 mmHg in the placebo group. Over time, a marked divergence in SBP trajectories was observed. In the intervention group, SBP decreased to 141.2 mmHg at week 4 and further to 135.4 mmHg at week 8, representing an overall reduction of approximately 13.2 mmHg from baseline. In contrast, the placebo group exhibited only a modest decline, with SBP values of 146.1 mmHg at week 4 and 145.2 mmHg at week 8, corresponding to a total reduction of 2.7 mmHg. The widening separation between group trajectories, together with partially non-overlapping 95% confidence intervals at later follow-up points, indicates a significantly greater reduction in SBP over time in the intervention group. This

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pattern is consistent with the significant group × time interaction observed in the linear mixed-effects model ($p < 0.01$) (Figure 1).

A similar pattern was observed for diastolic blood pressure. Baseline estimated marginal mean DBP was 92.4 mmHg in the intervention group and 91.8 mmHg in the placebo group. Participants receiving Passiflora edulis juice experienced a progressive decline in DBP to 88.1 mmHg at week 4 and 84.3 mmHg at week 8, yielding an overall reduction of 8.1 mmHg. In contrast, the placebo group showed minimal change, with DBP decreasing slightly to 91.2 mmHg at week 4 and 90.7 mmHg at week 8, corresponding to a total reduction of 1.1 mmHg. The distinct downward trajectory in the intervention group and the relatively stable pattern in the placebo group resulted in a clear between-group separation over time. The confidence intervals indicate that this difference is unlikely to be due to random variation, consistent with the statistically significant group × time interaction for DBP ($p < 0.01$).

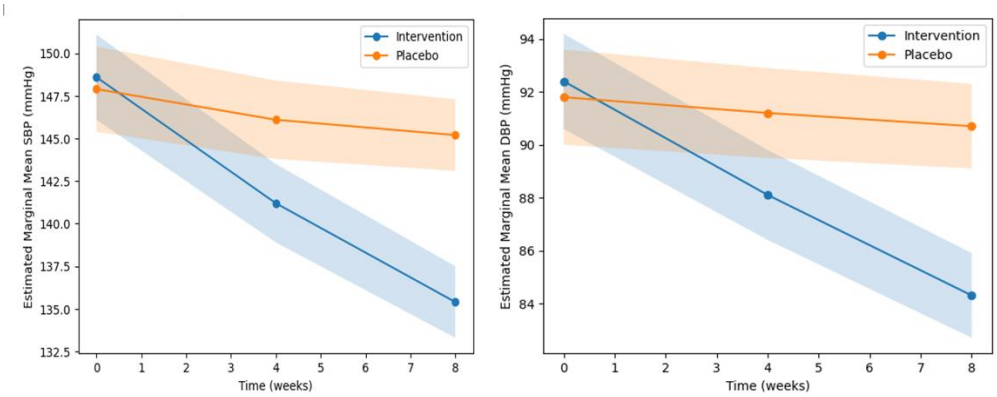

Figure 1. Estimated marginal means (EMMs) of systolic and diastolic blood pressure

4. DISCUSSION

This randomized, double-blind, placebo-controlled clinical trial demonstrated that daily consumption of Passiflora edulis juice as a complementary intervention resulted in a statistically and clinically significant reduction in both systolic and diastolic blood pressure among patients with hypertension over an eight-week period. Participants receiving Passiflora edulis juice experienced a mean reduction of approximately 13.2 mmHg in systolic blood pressure (SBP) and 8.1 mmHg in diastolic blood pressure (DBP), whereas changes observed in the placebo group were minimal. These findings remained robust after adjustment for relevant covariates and were further supported by consistent results in sensitivity analyses. The magnitude of blood pressure reduction observed in the intervention group is clinically meaningful. Prior epidemiological evidence indicates that a reduction of 10 mmHg in SBP or 5 mmHg in DBP is associated with substantial decreases in the risk of major cardiovascular events, including stroke and coronary heart disease (Semánová, 2021). Therefore, the observed reductions suggest potential cardiovascular benefit beyond statistical significance, particularly when integrated with standard pharmacological therapy.

Direct human clinical trials evaluating Passiflora edulis juice consumption in hypertensive populations are scarce. Most existing evidence derives from preclinical studies or investigations using extracts and by-products of P. edulis. Animal studies have reported antihypertensive effects

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of P. edulis peel extracts, attributing blood pressure reduction to improved endothelial function and antioxidant activity (Cabral et al., 2022). While these findings provide mechanistic plausibility, they do not reflect typical dietary consumption patterns. The present study extends this evidence by demonstrating that whole-fruit juice consumption can elicit clinically relevant blood pressure reductions in humans with established hypertension. Systematic reviews of P. edulis by-products have emphasized their rich polyphenolic content and potential role in cardiovascular risk reduction (Weyya et al., 2024). However, such reviews also highlight the heterogeneity of preparations, doses, and study designs, limiting direct clinical translation. The current trial addresses this gap by employing a standardized juice preparation and a rigorous randomized controlled design. Evidence from related Passiflora species further contextualizes the present findings. A quasi-experimental study involving Passiflora foetida leaf decoction reported reductions in blood pressure among hypertensive adults (Candra et al., 2023). Nevertheless, interspecies variation in phytochemical composition precludes direct extrapolation. The present study specifically demonstrates the efficacy of P. edulis, the most commonly consumed Passiflora species, thereby strengthening its relevance to dietary and public health contexts.

Beyond Passiflora-specific literature, the findings are consistent with broader evidence supporting the antihypertensive effects of polyphenol-rich dietary interventions. Recent reviews have shown that dietary polyphenols can modulate vascular tone through enhanced nitric oxide bioavailability, reduced oxidative stress, and attenuation of inflammatory pathways (Gai et al., 2023). These mechanisms align with the observed sustained reductions in SBP and DBP and support the biological plausibility of the intervention. The blood pressure reductions observed in this trial may be biologically plausible through several pathways previously proposed for Passiflora edulis and other polyphenol-rich foods. Polyphenols and flavonoids may enhance endothelial nitric oxide bioavailability, thereby promoting vasodilation and improving vascular tone. Antioxidant compounds may reduce oxidative stress and preserve endothelial function, while anti-inflammatory effects and potential modulation of the renin–angiotensin system may further contribute to blood pressure regulation. However, because biomarkers such as nitric oxide metabolites, oxidative stress markers, inflammatory markers, and renin–angiotensin activity were not measured in the present study, these mechanisms should be interpreted as plausible hypotheses rather than confirmed biological pathways.

The findings of this study have important implications for hypertension management. First, *Passiflora edulis* juice appears to be a safe and well-tolerated complementary intervention, as no serious adverse events were observed and only mild, self-limiting gastrointestinal symptoms were reported. This favorable safety profile is consistent with existing pharmacological and nutritional evidence indicating that *Passiflora edulis*, when consumed as a food-based product, is generally well tolerated and has not been associated with major safety concerns in cardiometabolic research contexts (He et al., 2020). Second, the absence of significant differences in medication adherence between the intervention and placebo groups strengthens the interpretation that the observed reductions in blood pressure were independent of pharmacological compliance. This finding aligns with previous validation studies demonstrating that the Hill-Bone Compliance to High Blood Pressure Therapy Scale is a reliable tool for detecting adherence-related confounding in hypertension research (Commodore-Mensah et al., 2023). Given its accessibility, cultural

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acceptability, and low cost in many regions, *Passiflora edulis* juice may serve as a practical adjunct rather than a substitute—to standard antihypertensive therapy, consistent with current international hypertension guidelines that emphasize the integration of dietary and lifestyle strategies alongside pharmacological treatment (Mancia et al., 2023).

5. STUDY LIMITATIONS

Several limitations should be acknowledged. First, the intervention duration was limited to eight weeks, which precluded assessment of long-term sustainability of blood pressure reductions. Second, the study was conducted at a single outpatient clinic, which may limit generalizability to broader hypertensive populations or other healthcare settings. Third, dietary sodium intake, physical activity, body weight changes, and other lifestyle factors were not comprehensively controlled or objectively measured. Fourth, although beverage adherence was monitored through intake logs and weekly follow-up contacts, adherence assessment relied primarily on participant reports. Fifth, laboratory quantification of phytochemical compounds was not performed, and biomarkers related to nitric oxide bioavailability, oxidative stress, endothelial function, inflammation, or renin–angiotensin activity were not measured. Therefore, mechanistic explanations remain hypothetical and require further investigation.

6. CONCLUSION

This randomized, double-blind, placebo-controlled trial found that daily consumption of Passiflora edulis juice as a complementary intervention reduced systolic and diastolic blood pressure among patients with hypertension over an eight-week period. The magnitude of reduction was clinically meaningful, and the intervention was generally well tolerated. These findings support the potential role of Passiflora edulis juice as an adjunctive dietary strategy within comprehensive hypertension management, rather than as a replacement for standard antihypertensive therapy. However, given the short intervention duration, single-center design, absence of phytochemical quantification, and lack of mechanistic biomarker assessment, further multicenter randomized trials with larger samples, longer follow-up, objective lifestyle monitoring, and mechanistic endpoints are needed before widespread clinical implementation can be recommended.

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9. AUTHOR CONTRIBUTIONS

RZ: Conceptualization, methodology, investigation, data collection, formal analysis, writing – original draft, and supervision. IR: Methodology, validation, data interpretation, writing – review and editing. MPG: Statistical analysis, data curation, visualization, writing – review and editing. All authors have read and approved the final manuscript.

10. CONFLICT OF INTEREST

The authors declare no conflict of interest related to the conduct, authorship, or publication of this study.

11. DATA AVAILABILITY STATEMENT

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request, in accordance with ethical approval and participant confidentiality requirements.

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