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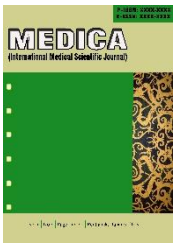

Effect of Tamarillo Juice Consumption on Hemoglobin Levels and Wound Healing in Patients with Diabetic Foot Ulcers

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Abstract

Anemia is a common but often overlooked complication in patients with diabetic foot ulcers (DFUs), and reduced hemoglobin levels are associated with delayed wound healing and adverse clinical outcomes. This study aimed to evaluate the effect of tamarillo (Solanum betaceum) juice consumption on hemoglobin levels and wound healing in patients with diabetic foot ulcers in Poso Regency, Indonesia. A quasi-experimental study with a pretest–posttest control group design was conducted involving 38 patients with diabetic foot ulcers receiving treatment at independent nursing practices. Participants were assigned to either an intervention group, which consumed 250 mL of tamarillo juice daily for four weeks in addition to standard wound care, or a control group that received standard wound care alone. Hemoglobin levels were measured using a calibrated hematology analyzer, while wound healing was assessed using the Bates-Jensen Wound Assessment Tool before and after the intervention. Data were analyzed using paired and independent statistical tests according to data distribution, with a significance level of $p < 0.05$. After four weeks, the intervention group demonstrated significantly higher hemoglobin levels than the control group (11.52 vs. 10.95 g/dL; $p = 0.019$) and significantly better wound healing outcomes, as indicated by lower Bates-Jensen scores (22.11 vs. 32.32; $p < 0.001$). These findings suggest that tamarillo juice may serve as a beneficial adjunctive nutritional intervention for improving hemoglobin levels and promoting wound healing in patients with diabetic foot ulcers. However, given the quasi-experimental design and relatively small sample size, further large-scale randomized controlled trials are warranted to confirm these findings and establish their clinical applicability.

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1. INTRODUCTION

Diabetes mellitus (DM) represents one of the most rapidly expanding global health challenges, currently affecting approximately 589 million adults aged 20–79 years worldwide (IDF, 2025). Among its most feared complications is the diabetic foot ulcer (DFU), which accounts for more than 60% of all non-traumatic lower extremity amputations worldwide. It is estimated that a new DFU occurs every 20 seconds globally, rendering effective management an urgent clinical imperative (Aditya et al., 2025). Furthermore, approximately 42% of patients who have recovered from a DFU experience ulcer recurrence within one year, underscoring the significant chronic burden imposed on healthcare systems (Armstrong et al., 2023). In independent nursing practice settings in Poso Regency, the number of patients receiving DFU care has progressively increased, with the majority presenting with recurrent wounds requiring more than one month of treatment.

Wound healing in individuals with DM is impaired by a complex array of pathophysiological mechanisms. Delayed DFU healing is attributable to multiple contributing factors, including diminished neurotrophic support, impaired neuropeptide production, inadequate cutaneous blood flow secondary to microangiopathy, abnormal scarring, excessive inflammation, defective keratinocyte migration, and impaired mechanosensory adaptation (Aditya et al., 2025). One clinical dimension that has received insufficient attention in DFU management is hematological status. Anemia has been reported as a serious complication of DM and is consistently associated with poor wound healing outcomes, increased risk of amputation, and elevated mortality among DFU patients (Lee et al., 2024). Evidence further suggests that anemia in diabetic patients significantly increases the risk of DFU development (Lin et al., 2025). Anemia has been detected in the large majority of hospitalized DFU patients, with hemoglobin levels often continuing to decline during hospitalization despite optimal wound management (Kumar et al., 2023). Reduced hemoglobin concentrations directly diminish the oxygen-carrying capacity of blood to wound tissues, and markedly low serum levels of albumin, iron, and zinc have similarly been identified in DFU patients, suggesting that nutritional supplementation may support recovery (Lee et al., 2024) Consequently, therapeutic interventions capable of elevating hemoglobin levels while simultaneously supporting wound healing mechanisms hold considerable clinical and strategic value.

Tamarillo (*Solanum betaceum* Cav.), commonly known as tree tomato, has emerged as a promising nutraceutical candidate. This fruit is rich in secondary metabolites, including polyphenols, anthocyanins, carotenoids, vitamin C, and various other bioactive compounds. Scientific interest in tamarillo has continued to grow within the domains of food science, nutraceutical research, and biotechnology (Anticona Coello et al., 2026). The naturally occurring polyphenols present in tamarillo have demonstrated antioxidant, anticholinesterase, anti-inflammatory, antimicrobial, antidiabetic, and anti-obesity properties (Machado et al., 2024). Tamarillo contains nutritionally significant concentrations of iron and vitamin C; with a vitamin C content of 25 mg and an iron content of 2,765 ppm, it represents a potentially effective herbal agent for improving hemoglobin levels. A study conducted among pregnant women with anemia demonstrated a hemoglobin increase of 0.91 g/dL in the group receiving tamarillo juice, compared to only 0.43 g/dL in the control group receiving iron supplementation alone (Simbolon & Sitompul, 2021). Vitamin C plays a critical role as a cofactor that enhances the intestinal absorption of non-heme iron. Additionally, tamarillo is abundantly rich in phenolic compounds, anthocyanins, and carotenoids, and has been shown to possess potent antioxidant activity (Rito et al., 2023). This antioxidant capacity is relevant to DFU healing, given the role of oxidative stress in impairing tissue repair.

Previous research has demonstrated that tamarillo juice can elevate hemoglobin levels in individuals with general anemia. However, no studies have specifically examined its effects in patients with DM complicated by diabetic foot ulcers. Moreover, the existing body of scientific evidence remains limited and methodologically heterogeneous, particularly with respect to its efficacy under specific clinical conditions (Anticona Coello et al., 2026). This evidence gap therefore constitutes the primary rationale for the present study. This study aims to analyze the effect of tamarillo (*Solanum betaceum* Cav.) juice consumption on hemoglobin levels and diabetic foot ulcer healing. The findings are expected to provide a scientific foundation for the development of locally accessible, affordable, food-based nutraceutical interventions that can be comprehensively integrated into DFU management protocols.

2. METHOD

This study employed a quasi-experimental design with a pre-test and post-test control group design. The study population comprised all patients with diabetic foot ulcers receiving wound care at an independent nursing practice clinic. Participants were recruited using purposive sampling. Inclusion criteria were as follows: willingness to participate as a study respondent, presence of a diabetic foot ulcer classified as Wagner grade II–IV, satisfactory general condition, and absence of active wound bleeding. Exclusion criteria included wounds complicated by gas gangrene infection, limb ischemia, and the presence of epigastric pain. The minimum sample size was determined a priori using a two-group mean comparison formula at $\alpha = 0.05$ and 80% power, and an anticipated medium effect size based on previous studies evaluating nutritional interventions for diabetic foot ulcer healing. The calculated minimum sample size was 19 participants per group (38 participants in total).

A total of 38 respondents were enrolled and randomly allocated into two groups of 19 participants each using simple random allocation by the lottery method. Baseline demographic and clinical characteristics, including age, sex, education, occupation, and ulcer severity, were compared between the two groups prior to the intervention to assess baseline comparability. Participants were then assigned to either an intervention group, which received tamarillo juice daily for four consecutive weeks, and a control group, which did not receive tamarillo juice. Both groups received standard wound care delivered by certified wound care nurses. Participants in the intervention group consumed 250 mL of tamarillo fruit juice daily throughout the four-week intervention period. The juice was prepared from fresh tamarillo fruit. The fruit was cleaned, washed, and thinly peeled, then cut into several pieces and blended with the addition of water to yield a total volume of 250 mL per serving (Muliarta et al., 2020).

Hemoglobin levels were measured using the impedance method with a calibrated hematology analyzer. Wound healing was assessed as the progression of healing across the following parameters: wound size, depth, edges, undermining, necrotic tissue, exudate characteristics, periwound skin condition, edema, wound margins, granulation tissue, and epithelialization. These parameters were evaluated using the Bates-Jensen Wound Assessment Tool (BJWAT). Both hemoglobin levels and wound healing status were measured at two time points: prior to the intervention (pre-test) and upon completion of the intervention period (post-test). Data normality was assessed using the Shapiro–Wilk test. Within-group pre- and post-intervention differences were analyzed using the paired samples t-test for normally distributed data and the Wilcoxon signed-rank test for non-normally distributed data, while between-group post-intervention differences were analyzed using the independent samples t-test, all at a significance level of $\alpha = 0.05$. Outcome assessments were performed independently by certified wound care nurses who

were blinded to group allocation whenever feasible to minimize observer bias. Participant blinding was not feasible because of the nature of the dietary intervention. The study protocol was reviewed and approved by the Health Research Ethics Committee of Poltekkes Kemenkes Palu Approval No.0097/KEPK-KPK/VIII/2024, and written informed consent was obtained from all participants prior to enrollment.

3. RESULTS AND DISCUSSION

Table 1. Respondent Characteristics by Age, Educational Level, Sex, and Occupation.

Characteristics	Frequency	Percentage (%)
Age		
21-35 years	1	2.6
36-50 years	15	39.5
51-65 years	19	50
≥ 66 years	3	7.9
Sex		
Male	22	57.9
Female	16	42.1
Educational Level		
Primary School	10	26.3
Junior High School	6	15.8
Senior High School	14	36.8
Higher Education	8	21.1
Occupation		
Civil Servant	6	15.8
Private Employee	12	31.6
Retired	6	15.8
Housewife	7	18.4
Farmer	7	18.4

Table 1 presents the sociodemographic characteristics of the study participants. The majority of respondents were aged 51–65 years (50.0%), followed by those aged 36–50 years (39.5%), ≥ 66 years (7.9%), and 21–35 years (2.6%). With respect to sex distribution, 57.9% of respondents were male, and 42.1% were female. Regarding educational attainment, the largest proportion had completed senior high school (36.8%), followed by primary school (26.3%), higher education (21.1%), and junior high school (15.8%). In terms of occupational status, the majority were private sector employees (31.6%), followed by homemakers and farmers, each accounting for 18.4% of respondents, while civil servants and retirees each comprised 15.8% of the study sample.

Table 2. Mean Differences in Hemoglobin Levels Before and After Intervention in Diabetic Foot Ulcer Patients.

Group	Mean	*p-value*
Tamarillo Juice Consumption		
Hemoglobin Pre-test (g/dL)	10.36	0.000
Hemoglobin Post-test (g/dL)	11.52	
Without Tamarillo Juice Consumption		
Hemoglobin Pre-test (g/dL)	10.25	0.000
Hemoglobin Post-test (g/dL)	10.95	

Table 2 presents the mean hemoglobin levels of diabetic foot ulcer patients in both groups before and after the intervention. In the intervention group, the mean hemoglobin level prior to the intervention was 10.36 g/dL, which increased to 11.52 g/dL following the intervention period. Statistical analysis using the paired sample t-test yielded a p-value of 0.000, indicating a statistically significant difference in mean hemoglobin levels before and after tamarillo juice consumption. In the control group, the mean hemoglobin level before the intervention was 10.25 g/dL, rising to 10.95 g/dL after the intervention period. Statistical analysis similarly demonstrated a statistically significant difference, with a paired sample t-test yielding a p-value of 0.000.

Table 3. Mean Differences in Wound Healing Scores Before and After Intervention in Diabetic Foot Ulcer Patients.

Group	Mean Score	p-value
Tamarillo Juice Consumption		
Pre-test Score	47.63	0.000
Post-test Score	22.11	
Without Tamarillo Juice Consumption		
Pre-test Score	47.32	0.012
Post-test Score	32.32	

Table 3 demonstrates that the mean wound healing score in the intervention group prior to the intervention was 47.63, which decreased to 22.11 following the intervention period. Statistical analysis using the Wilcoxon signed-rank test yielded a p-value of 0.000, indicating a statistically significant reduction in mean wound healing scores before and after tamarillo juice consumption. In the control group, the mean wound healing score before the intervention was 47.32, decreasing to 32.32 after the intervention period. Statistical analysis using the paired sample t-test yielded a p-value of 0.012, indicating a statistically significant difference in mean wound healing scores before and after the intervention.

Table 4. Comparison of Hemoglobin Levels and Wound Healing Scores After Intervention in Diabetic Foot Ulcer Patients.

Variable	Mean	p-value
Hemoglobin Level (g/dL)		
Tamarillo Juice Consumption	11.52	0.019
Without Tamarillo Juice Consumption	10.95	
Wound Healing Score		
Tamarillo Juice Consumption	22.11	0.000
Without Tamarillo Juice Consumption	32.32	

Table 4 presents the post-intervention mean hemoglobin levels, recorded at 11.52 g/dL in the intervention group and 10.95 g/dL in the control group. Statistical analysis using the independent samples t-test yielded a p-value of 0.019 ($p < \alpha = 0.05$), indicating a statistically significant difference in mean hemoglobin levels between the intervention and control groups following the intervention. With respect to wound healing scores, the post-intervention mean was 22.11 in the intervention group and 32.32 in the control group. Statistical analysis using the independent samples t-test yielded a p-value of 0.000 ($p < \alpha = 0.05$), demonstrating a statistically significant difference in mean wound healing scores between the two groups after the intervention.

The present study provides evidence that consumption of tamarillo (*Solanum betaceum* Cav.) juice significantly improved hemoglobin levels and accelerated wound healing in diabetic foot ulcer patients. The intervention group demonstrated an increase in mean hemoglobin from 10.36 to 11.52 g/dL ($p = 0.000$) and a reduction in wound healing scores from 47.63 to 22.11 ($p = 0.000$), with statistically significant differences compared to the control group following the four-week intervention period ($p = 0.019$ and $p = 0.000$, respectively). These findings support the study hypothesis that tamarillo exerts clinically relevant therapeutic effects in patients with diabetic foot ulcers (DFU).

The improvement in hemoglobin levels observed in the intervention group may be explained by the synergistic interaction between the iron and vitamin C content of tamarillo. *Solanum betaceum* is a fruit rich in secondary metabolites, with a vitamin C content ranging from 12 to 50 mg per 100 g of fresh fruit (Anticona Coello et al., 2026). scorbic acid (vitamin C) serves as a key enhancer of non-heme iron absorption, and the vitamin C present in tamarillo has been shown to increase iron absorption up to fourfold. Given that iron is an essential precursor in hemoglobin synthesis, regular consumption of tamarillo juice may consequently elevate hemoglobin concentrations in DFU patients. These findings are consistent with a previous study demonstrating that tamarillo juice significantly increased hemoglobin levels in pregnant women with anemia (Simbolon & Sitompul, 2021).

The mechanism underlying accelerated wound healing can be understood from the perspective of oxidative stress and inflammatory response dysregulation. In diabetic conditions, chronic hyperglycemia triggers excessive production of reactive oxygen species (ROS). Hyperglycemia induces activation of nuclear factor kappa B (NF-κB), which promotes the overproduction of pro-inflammatory cytokines — including tumor necrosis factor-alpha (TNF-α), interleukin-6 (IL-6), and interleukin-1 beta (IL-1β) — thereby perpetuating chronic inflammation and impeding wound healing (Burgess et al., 2021). The imbalance between free radicals and the endogenous antioxidant system results in excessive ROS production, leading to cellular and tissue damage that further delays healing. Tamarillo possesses a rich bioactive composition encompassing proteins, vitamins A and C, minerals, dietary fiber, flavonoids, carotenoids, anthocyanins, and other phytochemicals; its naturally occurring polyphenols have demonstrated antioxidant, anti-inflammatory, antimicrobial, antidiabetic, and anti-obesity properties (Wang & Zhu, 2019). Flavonoids have been shown to promote wound healing through anti-inflammatory, pro-angiogenic, re-epithelialization, and antioxidant mechanisms, operating via the NF-κB, Nrf2/ARE, and TGF-β signaling pathways (Zulkefli et al., 2023). Accordingly, the inhibition of oxidative stress and the improvement of hemoglobin levels appear to act synergistically. Elevated hemoglobin directly contributes to wound healing by enhancing tissue oxygenation capacity, as oxygen is indispensable for critical wound repair processes including collagen deposition, epithelialization, fibroplasia, and angiogenesis. Impaired delivery of oxygenated blood to wound tissue significantly delays healing by compromising cellular function and increasing susceptibility to infection (Frykberg et al., 2023).

Antioxidants are molecules capable of inhibiting oxidative reactions. In both acute and chronic wounds, the enzymatic expression of antioxidants is upregulated; however, their activity is diminished due to the overwhelming influence of oxidative stress, which depletes non-enzymatic antioxidant reserves — an effect that is more pronounced in chronic wounds than in acute wounds. Supplementation with antioxidants supports wound healing by attenuating oxidative cellular damage (Arief & Widodo, 2018).

The findings of the present study are consistent with several investigations examining antioxidant-rich herbal plants in DFU management. *Solanum betaceum* extract has been shown to exhibit potent antioxidant activity against free radicals and to inhibit

lipid peroxidation, mechanisms that are mechanistically relevant to the prevention of diabetes-related complications (Faradist et al., 2024). A metabolomic study identified twelve polyphenols in tamarillo via LC-MS/MS, including ellagic acid, rutin, catechin, and epicatechin, with the highest antioxidant activity observed in cultivars with the greatest phenolic compound and anthocyanin content (T. Diep et al., 2020). Tamarillo extract has further demonstrated effective anti-inflammatory activity (Salsabila & Sudiono, 2022).

This study is among the first to directly examine the clinical effects of tamarillo juice in a human DFU population; therefore, direct comparisons with equivalent studies remain limited. Notably, the control group also demonstrated a significant improvement in wound healing scores (from 47.32 to 32.32, $p = 0.012$), confirming the effectiveness of standard wound care; however, the magnitude of improvement in the intervention group was statistically superior, thereby reinforcing the specific therapeutic contribution of tamarillo beyond standard care. With respect to hemoglobin outcomes, these findings corroborate prior research on the association between anemia and DFU. A previous study reported that each 1 g/dL decrease in hemoglobin was associated with an increased risk of DFU (OR: 1.65), and that diabetic patients with DFU exhibited significantly lower hemoglobin levels compared to those without DFU (Lin et al., 2025). Furthermore, anthocyanins have been shown to suppress ROS signaling, modulate the NF-κB pathway, and promote type I collagen synthesis in primary dermal fibroblasts, indirectly supporting the wound healing mechanisms proposed in the present study (Faradist et al., 2024). Natural compounds, including flavonoids, have demonstrated potential in enhancing diabetic wound healing by reducing oxidative stress and attenuating inflammatory responses (Guo et al., 2025).

These findings open promising avenues for the use of tamarillo as an affordable, herbal-based complementary therapy in DFU management, particularly within primary healthcare settings and independent nursing practices in regions with limited access to costly pharmacological interventions. The hemoglobin-elevating potential of tamarillo carries meaningful prognostic relevance, given that anemia is recognized as an independent risk factor for adverse outcomes in DFU. Natural extracts, including flavonoids, have been shown to enhance wound healing through modulation of oxidative stress and promotion of collagen synthesis, further supporting the therapeutic potential of herbal agents such as tamarillo in managing diabetic foot ulcers (Nandhini et al., 2024). Additional evidence confirms that low hemoglobin constitutes an independent protective factor against amputation (OR: 0.742; 95% CI: 0.638–0.965), underscoring the necessity of anemia management as an integral component of comprehensive DFU care (Zhang et al., 2024).

These findings hold significant relevance for diabetes management and complication prevention programs at the community level, particularly in regions with a high DFU prevalence and limited access to specialized healthcare infrastructure. The implementation of this intervention within an independent nursing practice setting, as demonstrated in this study, further reflects the pivotal role of community nurses as frontline providers of holistic diabetic wound management. This study makes an original and meaningful scientific contribution as one of the first clinical trials to directly examine the effects of tamarillo (*Solanum betaceum* Cav.) juice intervention on hemoglobin levels and diabetic foot ulcer healing in humans within an independent nursing practice setting. Tamarillo is a nutritionally diverse fruit containing polyphenols, vitamins C, A, B, and E, carotenoids, potassium, and iron, with health-promoting properties encompassing antioxidative, antiproliferative, and anti-inflammatory effects, collectively establishing tamarillo as a promising source of high-value health products (Diep et al., 2022). The novelty of this study lies in the clinical validation of tamarillo's therapeutic effects in a DFU population, thereby enriching the evidence base for herbal complementary therapies and

opening new research pathways for the development of standardized phytopharmaceutical products derived from the Solanaceae family within the framework of evidence-based medicine in developing countries.

Several limitations of this study should be acknowledged. Although hemoglobin levels increased significantly more in the intervention group than in the control group, the absolute difference in mean improvement (Δ = 1.16 g/dL in the intervention group versus Δ = 0.70 g/dL in the control group) was modest; future studies should evaluate whether this magnitude of change translates into clinically meaningful outcomes, such as reduced transfusion need or improved tissue oxygenation. The quasi-experimental design, while incorporating random allocation, did not include participant blinding (which was not feasible given the nature of the dietary intervention), and formal baseline-equivalence testing between groups was not reported. The relatively small, single-site sample also limits the generalizability of these findings. In addition, potential confounding variables known to influence both hemoglobin levels and wound healing such as glycemic control (HbA1c), nutritional status, comorbidities, and medication use were not measured or statistically adjusted for. Finally, the four-week follow-up period may be insufficient to capture the full trajectory of wound healing. Future research using larger, multi-center randomized controlled trials with extended follow-up and adjustment for relevant confounders is needed to confirm these preliminary findings.

4. CONCLUSION

The findings of this study indicate that tamarillo juice consumption is associated with significantly greater improvement in hemoglobin levels and wound healing in diabetic foot ulcer patients compared with standard care alone. Given the quasi-experimental design and modest sample size, these results should be regarded as preliminary evidence rather than definitive proof of efficacy. Nursing practitioners may consider introducing tamarillo juice consumption as a low-cost, complementary educational strategy for diabetic foot ulcer patients, alongside standard wound care, while further large-scale, multi-center randomized controlled trials with longer follow-up are conducted to confirm these findings and establish their clinical significance.

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