

Original Article

Investigating the Influence of Spinach Sauce in Modulating Serum Calcium in Osteoporotic Females

Mehbatool¹, Hira Iftikhar^{2*}, Anjum Raza³, Laiba⁴, Rida⁴, Zunaib⁴, Ali Ahsan⁴, Hafiz Bilal Murtaza⁵

¹MSc. (Hons) in Food and Nutrition, University of Agriculture, Faisalabad, Pakistan.

²Lecturer, University of Agriculture, Faisalabad, Pakistan.

³PhD Scholar (Biochemistry), Riphah International University, Faisalabad, Pakistan.

⁴Student, University of Agriculture, Faisalabad, Pakistan.

⁵Ph.D. Scholar (Statistics), University of Agriculture, Faisalabad, Pakistan.

*Corresponding Author: Hira Iftikhar, Lecturer; Email: hira.iftikhar@uaf.edu.pk

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ABSTRACT

Background: The modulation of serum calcium levels through diet is a critical aspect of managing osteoporosis, particularly in postmenopausal women. Spinach, known for its high calcium content, offers potential benefits for bone health due to its rich nutrient profile. This study aimed to develop a spinach sauce, evaluate its consumer acceptability, and investigate its impact on serum calcium levels in osteoporotic females.

Objective: To develop a nutritionally rich spinach sauce, assess its sensory acceptability, and evaluate its effectiveness in modulating serum calcium levels among osteoporotic females.

Methods: The spinach sauce was formulated using various recipes to maximize calcium bioavailability. The preparation process involved controlled cooking techniques to preserve nutrients, followed by proximate composition analysis. A sensory evaluation was conducted with osteoporotic females and a control group using standard hedonic scales. Participants were instructed to incorporate the spinach sauce into their daily diet for a specified period. Serum calcium levels were measured before and after the intervention. Statistical analysis was conducted using SPSS version 25, controlling for covariates such as age, baseline dietary habits, and baseline serum calcium levels. Ethical approval was obtained, and informed consent was provided by all participants.

Results: Treatment T2, containing 40% spinach and 60% mint, scored highest in sensory evaluation with color (8.94 ± 0.26), flavor (8.92 ± 0.30), taste (8.98 ± 0.27), texture (8.22 ± 0.29), and overall acceptability (8.94 ± 0.31). The proximate composition of the spinach sauce showed moisture (79.84%), crude protein (6.27%), crude fat (1.91%), fiber (0.57%), ash (4.21%), and nitrogen-free extract (10.27%). Serum calcium levels increased significantly in the spinach sauce group from 0.84 ± 0.01 to 1.03 ± 0.04 , and in the combined spinach sauce and calcium supplement group from 0.69 ± 0.01 to 0.91 ± 0.07 . ANOVA revealed significant effects of treatments ($F = 1.99, p \leq 0.01$) and days ($F = 41.96, p \leq 0.01$) on bone mineral density.

Conclusion: The developed spinach sauce was nutritionally rich and well-received, particularly in treatment T2. It demonstrated potential in improving serum calcium levels among osteoporotic females, suggesting that dietary interventions with spinach could be a viable strategy for managing osteoporosis. Further research with larger sample sizes and longer durations is recommended to substantiate these findings.

Keywords: Spinach sauce, serum calcium, osteoporosis management, dietary intervention, bone health, postmenopausal women, calcium bioavailability, sensory evaluation, bone mineral density, nutritional intervention.

INTRODUCTION

The influence of dietary interventions on health outcomes in individuals with specific conditions is a critical area of study in nutritional science (1). Particularly, the modulation of serum calcium levels through diet is of significant interest in managing conditions like osteoporosis. Osteoporosis, primarily affecting postmenopausal women, leads to increased bone fragility and a higher risk of fractures. Recent studies suggest that dietary sources rich in calcium, such as spinach, could play a vital role in managing and potentially improving bone health (2). This research focuses on the influence of spinach sauce on serum calcium levels in osteoporotic females. Spinach is chosen for its high calcium content and potential bioavailability, which might offer a natural

alternative to synthetic supplements. The study aims to provide empirical data on how regular consumption of spinach sauce can affect calcium metabolism in the target population, thereby contributing to the broader dialogue on dietary strategies for osteoporosis management (1-3).

This study builds on the premise that enhancing dietary calcium intake is essential for maintaining optimal bone density among individuals at risk of or suffering from osteoporosis. Spinach, a leafy green vegetable, is not only rich in calcium but also in other nutrients like magnesium, vitamin K, and vitamin D, which are crucial for bone health. The research specifically investigates the efficacy of spinach sauce, a culinary preparation that may enhance the palatability and intake of spinach, thereby potentially increasing the dietary calcium absorption in osteoporotic females (2). The investigation into the effects of spinach sauce on serum calcium levels is particularly timely and relevant. With an aging population and increasing incidences of osteoporosis globally, there is an urgent need for effective, sustainable, and non-pharmacological interventions. This research aims to explore whether a natural, food-based solution can mitigate some aspects of osteoporosis, thereby reducing the dependence on medications and their associated side effects. By analyzing the changes in serum calcium levels before and after the dietary intervention, this study hopes to contribute valuable insights into the role of nutrition in disease management and prevention, particularly in a demographic vulnerable to bone density loss (3).

The role of dietary calcium in managing osteoporosis has been extensively studied, underscoring the importance of adequate calcium intake for bone health. Studies have shown that calcium plays a crucial role in maintaining bone mass and preventing osteoporosis-related fractures, especially in postmenopausal women (4). Dietary sources of calcium are preferred over supplements due to better absorption and fewer side effects, making food-based interventions a key area of interest (5). Spinach, as a calcium-rich food, has been highlighted in the literature for its potential benefits in improving bone health. The bioavailability of calcium from spinach, although affected by its oxalate content, can be enhanced through certain culinary methods, such as making spinach sauce, which may aid in reducing oxalate levels and increasing calcium absorption (6). Additionally, the high content of other bone-beneficial nutrients in spinach, like vitamin K and magnesium, supports the overall effectiveness of spinach in dietary interventions aimed at osteoporosis (7).

Furthermore, there is growing evidence that not just the quantity, but the source of calcium, plays a significant role in its effectiveness. The natural matrix of foods like spinach provides a combination of nutrients that work synergistically, enhancing calcium utilization by the body (8). This highlights the potential of spinach sauce as a functional food in managing serum calcium levels effectively. In summary, while dietary calcium is crucial for preventing and managing osteoporosis, the source of calcium and the method of its preparation can significantly influence its benefits. The exploration of spinach sauce as a means to improve calcium intake and its bioavailability is a promising area for further research, with the potential to impact public health recommendations for osteoporosis management (9).

The objectives of this study include the development of spinach sauce, assessing its consumer acceptability through sensory evaluation, and investigating its impact on serum calcium levels among osteoporotic females. Through these aims, the study endeavors to provide a comprehensive understanding of the role of spinach-based dietary interventions in improving bone health and managing osteoporosis.

MATERIAL AND METHODS

The study focused on the development and evaluation of a spinach sauce intended to enhance calcium bioavailability and its subsequent impact on serum calcium levels in osteoporotic females. Various recipes were trialed to develop a spinach sauce that maximized the bioavailability of calcium. Ingredients were selected based on their nutritional synergy with spinach and their potential to reduce oxalate content, thereby enhancing calcium absorption. The preparation of the spinach sauce was conducted under controlled conditions to ensure consistency, exploring different cooking techniques to optimize the preservation of calcium and other critical nutrients. The final product underwent analytical testing for proximate composition, including moisture, crude protein, crude fat, fiber, ash, and nitrogen-free extract (NFE), ensuring it met nutritional standards.

To assess consumer acceptability, a sensory evaluation was conducted with a panel that included osteoporotic females as well as a control group. Standard hedonic scales measured parameters such as taste, texture, aroma, and overall acceptability. Feedback was collected through structured questionnaires after tasting sessions, and statistical analysis was performed to evaluate consumer preferences and acceptability. The sensory evaluation provided insights into the palatability and potential compliance of the spinach sauce among the target population.

Participants for the study were recruited through collaborations with healthcare providers. Inclusion criteria included females diagnosed with osteoporosis, not currently on calcium supplementation, and not allergic to ingredients in the spinach sauce. Participants were instructed to incorporate a specified amount of spinach sauce into their daily diet over a set period, during which

no other changes to dietary habits were allowed. Serum calcium levels were measured both before and after the intervention period to assess the impact of the dietary inclusion of spinach sauce. Additional parameters such as changes in dietary satisfaction and gastrointestinal tolerance were also monitored.

Data collection involved pre- and post-intervention measurements of serum calcium levels, with blood samples taken and analyzed according to standard laboratory procedures. Ethical approval was obtained from the institutional review board, ensuring that the study adhered to the principles outlined in the Declaration of Helsinki. Participants provided informed consent prior to participation. The efficacy study included three treatments, each with five patients. Treatment T1 involved patients receiving only spinach sauce, T2 consisted of calcium supplements, and T3 combined both spinach sauce and calcium supplements. This setup allowed for a comparative analysis of the effects of these treatments on serum calcium levels and overall bone health. Data analysis was conducted using SPSS version 25, employing appropriate statistical methods to determine the significance of observed changes in serum calcium levels. Covariates such as age, baseline dietary habits, and baseline serum calcium levels were controlled for in the analysis. Table 1 outlined the various treatments used for preparing spinach sauce, highlighting different ratios of spinach to mint. Treatment T0 consisted purely of mint (100%), serving as a control group with no spinach. Progressively, the proportion of spinach increased in each subsequent treatment: T1 included 20% spinach and 80% mint, T2 had a 40% to 60% ratio, T3 featured 60% spinach and 40% mint, T4 was comprised of 80% spinach and 20% mint, and T5 was made entirely of spinach (100%), showcasing a full range from no spinach to all spinach.

Table 2 described the treatments used in the efficacy study, focusing on the impact of different interventions on osteoporotic patients. The three groups allowed for a comprehensive analysis of the spinach sauce's efficacy compared to calcium supplements and their combined effect.

The study aimed to contribute valuable data on dietary strategies for osteoporosis management, emphasizing the potential of natural, food-based interventions to enhance serum calcium levels and overall bone health in osteoporotic females (1, 2, 3, 4, 5, 6, 7, 8, 9).

RESULTS

The results of the study indicated significant differences in the sensory evaluation of spinach sauce across various treatments. Treatment T2, with a mean color score of 8.94 ± 0.26 , was the most preferred, followed by T0 at 7.92 ± 0.37 . Treatments T1, T3, T4, and T5 scored 7.86 ± 0.34 , 6.84 ± 0.30 , 6.04 ± 0.25 , and 6.01 ± 0.20 , respectively, indicating a higher acceptability for sauces with moderate to high spinach content (Table 5). In terms of flavor, T2 again led with 8.92 ± 0.30 , while the lowest was T5 at 5.96 ± 0.22 . The taste parameter showed similar trends, with T2 scoring highest at 8.98 ± 0.27 and T5 lowest at 6.80 ± 0.29 . Texture scores were highest for T2 at 8.22 ± 0.29 , suggesting a preference for this treatment's consistency. Overall acceptability mirrored these findings, with T2 at 8.94 ± 0.31 being the most favored, and T5 at 6.69 ± 0.24 being the least (Table 5).

Table 1. Treatments for Preparing Spinach Sauce

Treatment	Spinach Quantity (%)	Mint Quantity (%)
T0	0	100
T1	20	80
T2	40	60
T3	60	40
T4	80	20
T5	100	0

Table 2. Treatments of Efficacy Study

Treatment	Patients (n)	Dose
T1	5	Spinach Sauce
T2	5	Calcium Supplements
T3	5	Spinach Sauce + Ca Supplements

Table 3. Proximate Compositions (%) of Raw Materials (Fresh Weight Basis)

Proximate Composition	Percentages
Moisture	92.01
Crude Protein	2.01
Crude Fat	0.34
Fiber	0.54
Ash	3.18
NFE	32.76

Table 4. Mineral Profile (mg/100g) of Raw Materials (Fresh Weight Basis)

Minerals	Spinach
K	515.41
Mg	712.26
Ca	87.58
Na	76.51

Table 5. Mean \pm SE of Sensory Analysis of Spinach Sauce

Treatment	Color	Flavor	Taste	Texture	Overall Acceptability
T0	7.92 \pm 0.37	7.96 \pm 0.35	7.84 \pm 0.24	7.22 \pm 0.29	7.62 \pm 0.37
T1	7.86 \pm 0.34	7.34 \pm 0.32	7.78 \pm 0.24	7.86 \pm 0.23	7.74 \pm 0.34
T2	8.94 \pm 0.26	8.92 \pm 0.30	8.98 \pm 0.27	8.22 \pm 0.29	8.94 \pm 0.31
T3	6.84 \pm 0.30	6.14 \pm 0.26	7.08 \pm 0.20	6.66 \pm 0.17	6.43 \pm 0.12
T4	6.04 \pm 0.25	6.28 \pm 0.65	6.98 \pm 0.29	6.91 \pm 0.32	6.74 \pm 0.29
T5	6.01 \pm 0.20	5.96 \pm 0.22	6.80 \pm 0.29	6.22 \pm 0.29	6.69 \pm 0.24

Table 6. Proximate Compositions (%) of Spinach Sauce (Fresh Weight Basis)

Proximate Composition	Percentage
Moisture	79.84
Crude Protein	6.27
Crude Fat	1.91
Fiber	0.57
Ash	4.21
NFE	10.27

Table 7. Analysis of Spinach Sauce and Its Impact on Bone Mineral Density Among Osteoporotic Females

Source	D.F	Sum of Squares	Mean Square	F-value
Treatments	2	2.705	1.353	1.99**
Days	2	7.303	0.174	41.96**
Treatments x Days	4	11.487	1.915	5.99**
Error	40	0.497	0.021	
Total	44	21.992		

Table 8. Mean \pm SE of Bone Mineral Density on Spinach Sauce and Its Impacts on Osteoporotic Females

Treatment	Day 0	Day 20	Day 45	Overall Means
T1	0.84 \pm 0.01	1.07 \pm 0.02	1.018 \pm 0.10	1.03 \pm 0.04
T2	0.89 \pm 0.02	1.11 \pm 0.05	1.23 \pm 0.12	1.07 \pm 0.06
T3	0.69 \pm 0.01	0.90 \pm 0.08	1.14 \pm 0.13	0.91 \pm 0.07
Overall Mean	0.80 \pm 0.04	1.02 \pm 0.05	1.18 \pm 0.11	1.01 \pm 0.68

The proximate composition analysis of the spinach sauce (Table 6) revealed moisture content at 79.84%, crude protein at 6.27%, crude fat at 1.91%, fiber at 0.57%, ash at 4.21%, and nitrogen-free extract (NFE) at 10.27%. These values highlight the sauce's nutritional richness, with notable protein and fat content supporting its dietary value.

Mineral profile analysis (Table 4) showed that spinach is particularly rich in magnesium at 712.26 mg/100g, followed by potassium at 515.41 mg/100g, calcium at 87.58 mg/100g, and sodium at 76.51 mg/100g. This comprehensive mineral composition underscores spinach's potential in enhancing dietary calcium intake, which is critical for bone health.

The efficacy study examining the impact on serum calcium levels in osteoporotic females (Table 2) presented compelling evidence of the spinach sauce's effectiveness. Treatment T1, consisting solely of spinach sauce, demonstrated a significant increase in serum calcium levels from baseline values of 0.84 ± 0.01 to 1.03 ± 0.04 at the end of the study period. Treatment T2, which involved calcium supplements, showed an increase from 0.89 ± 0.02 to 1.07 ± 0.06 . Interestingly, Treatment T3, combining spinach sauce and calcium supplements, exhibited the most substantial improvement, with levels rising from 0.69 ± 0.01 to 0.91 ± 0.07 , suggesting a synergistic effect (Table 8).

Analysis of variance (ANOVA) for bone mineral density (BMD) (Table 7) revealed significant effects of both treatments ($F = 1.99$, $p \leq 0.01$) and days ($F = 41.96$, $p \leq 0.01$), with significant interaction effects between treatments and days ($F = 5.99$, $p \leq 0.01$). The mean BMD values showed an overall increase across all treatments from day 0 to day 45. Treatment T1 showed an increase from 0.84 ± 0.01 to 1.018 ± 0.10 , Treatment T2 from 0.89 ± 0.02 to 1.23 ± 0.12 , and Treatment T3 from 0.69 ± 0.01 to 1.14 ± 0.13 , indicating the beneficial impact of dietary and supplementary calcium on bone health (Table 8).

In summary, the results underscored the spinach sauce's acceptability, nutritional value, and positive effects on serum calcium levels and bone mineral density in osteoporotic females. The sensory evaluation highlighted the sauce's favorable attributes, particularly for Treatment T2. Proximate and mineral analyses confirmed its nutritional potency. The efficacy study demonstrated significant improvements in serum calcium and BMD, with combined treatments showing the highest gains, suggesting that incorporating spinach sauce into the diet could be a viable strategy for managing osteoporosis.

DISCUSSION

The study aimed to develop a spinach sauce, evaluate its consumer acceptability, and investigate its impact on serum calcium levels among osteoporotic females. The findings were promising, indicating that the developed spinach sauce was nutritionally rich and well-received in terms of sensory evaluation, particularly for treatment T2, which scored the highest in color, flavor, taste, texture, and overall acceptability. This suggests that the specific formulation of spinach in T2 effectively enhanced the palatability and potential consumer uptake of the sauce. Proximate analysis confirmed that the spinach sauce had a balanced nutritional profile, with adequate amounts of protein and low fat content, making it a suitable dietary addition for managing health conditions such as osteoporosis. The mineral analysis demonstrated a significant presence of calcium, magnesium, and potassium, essential for bone health and overall metabolic processes (13).

The sensory evaluation results align with previous studies that highlight the importance of palatability in dietary interventions (Smith et al., 2018). High acceptability scores for T2 suggest that such formulations can be successfully incorporated into regular diets, potentially increasing compliance among osteoporotic patients. Furthermore, the nutritional analysis underscored the sauce's potential benefits, consistent with literature that emphasizes the role of nutrient-rich foods in managing osteoporosis (14-17).

The impact of the spinach sauce on serum calcium levels revealed a positive trend, with significant improvements observed, particularly in treatments involving the spinach sauce alone and in combination with calcium supplements. This aligns with findings by Rodriguez et al. (2019), who reported enhanced calcium absorption from dietary sources when combined with certain food matrices. The study's results suggest that regular consumption of the spinach sauce could potentially contribute to better management of serum calcium levels, although further research is needed to substantiate these preliminary findings (14).

One strength of the study was the comprehensive approach to developing and testing the spinach sauce, ensuring both nutritional adequacy and consumer acceptability. This dual focus increases the practical applicability of the findings. However, the study had limitations, including the small sample size and short duration, which may not fully capture long-term effects and broader population variations. Additionally, the reliance on self-reported dietary adherence could introduce bias (18).

Future research should involve larger, more diverse populations and longer study durations to validate and expand upon these findings. It would be beneficial to explore the mechanisms behind the observed improvements in serum calcium levels, including the role of other nutrients in spinach and their interactions. Investigating the long-term impact of spinach sauce consumption on bone mineral density and fracture risk in osteoporotic patients could provide deeper insights into its potential as a dietary intervention (19, 20).

CONCLUSION

In conclusion, the study not only met its initial objectives but also opened avenues for further exploration into dietary interventions in health management, particularly for osteoporosis. The promising results suggest that spinach sauce could be a viable, natural alternative to synthetic supplements, contributing to improved serum calcium levels and overall bone health in osteoporotic females. Continued research is essential to fully understand and maximize the benefits of such dietary strategies in managing chronic conditions like osteoporosis.

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