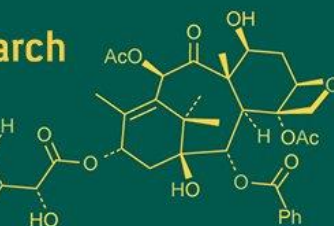
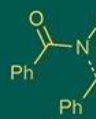


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Effect of infra-red heat treatment on the biochemical characteristics of little millet during storage

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Abstract

The present study evaluated the effect of Infra-Red (IR) heat treatment on the biochemical characteristics of little millet during storage. Untreated dehusked little millet (control) and little millet subjected to IR heat treatment followed by dehusking were packed in PET (400 µm) packaging material and stored under room temperature conditions for six months. The effect of IR heat treatment on the biochemical characteristics viz., proximate composition and anti-nutrients were evaluated at 30 days intervals. The results indicated that no significant differences were observed in the proximate composition and anti-nutritional factors between untreated dehusked little millet and IR heat treated dehusked little millet during the storage period, indicating that IR heat treatment did not adversely affect the nutritional quality of the grain.

Keywords: Little millet, LM-8437-17, Infra-Red (IR) heat treatment, biochemical characteristics, proximate composition, anti-nutrients

1. Introduction

Millets are a group of small-seeded cereal grains belonging to the family *Poaceae* and have been cultivated for centuries in Asia and Africa because of their ability to withstand drought, low soil fertility, and erratic rainfall. Their resilience and nutritional value have made them increasingly important for sustainable food systems under changing climatic conditions (Manik *et al.*, 2025; Meti *et al.*, 2024a and Meti *et al.*, 2024b)^[12, 13, 14].

Little millet commonly known as kutki, sawa, samai, and samalu, is one of the important minor millets cultivated in India and several Asian countries (Padulosi *et al.*, 2009)^[16]. It has gained considerable attention owing to its superior nutritional quality and potential health benefits. Little millet is a rich source of protein (10.0-15.0%), dietary fibre, essential minerals such as magnesium (120-133 mg/100 g) and phosphorus (251-260 mg/100 g), and bioactive compounds, making it a valuable ingredient for the development of functional foods (Veena *et al.*, 2005)^[19]. It also contains appreciable amounts of polyunsaturated fatty acids, flavonoids, and essential amino acids, including cysteine, methionine, and lysine, which contribute to its nutritional value (Indirani, 2021)^[8].

The grain is characterized by a low glycaemic index, high resistant starch, and slowly digestible carbohydrates, making it suitable for diabetic individuals and health-conscious consumers (Deshpande *et al.*, 2015; Chethan and Malleshi, 2007)^[4, 15]. In addition, its high dietary fibre content supports digestive health and contributes to improved metabolic well-being. These nutritional and functional attributes have increased the demand for little millet as a healthy alternative to conventional cereal grains. Despite its nutritional advantages, the presence of a tightly adhering husk poses challenges during milling, resulting in lower dehusking efficiency and reduced head grain yield. Infra-red (IR) heat treatment has emerged as an effective pre-milling treatment to overcome the challenges associated with husk removal. The rapid and uniform heating provided by infra-red heat weakens the adhesion between the husk and kernel, thereby improving dehusking efficiency and head grain yield (Kumar *et al.*, 2022; Oomah *et al.*, 2014 and Kumar *et al.*, 2009)^[9, 10, 15]. These findings highlight the potential of IR heat treatment as an efficient pre-processing technology for improving the milling performance of cereal and millet grains.

Storage is an important stage that influences the quality and shelf life of processed millets.

During storage, biochemical changes such as lipid oxidation, enzymatic activity, moisture redistribution, and degradation of bioactive compounds may affect their nutritional quality. Evaluating these changes in infra-red heat treated dehusked little millet provides insights into the effectiveness of the treatment that improve milling efficiency while preserving the nutritional quality of the grains throughout storage. Therefore, the present study was undertaken to investigate the effect of infra-red heat treatment on the biochemical characteristics of little millet during storage.

2. Materials and Methods

Sample preparation and storage conditions

Little millet (variety LM-8437-17) was procured from the Millet Processing Unit, University of Agricultural Sciences (UAS), Raichur, Karnataka, India. Infra-red (IR) heat treatment was carried out using the IR heat treatment unit developed at the Department of Processing and Food Engineering, UAS, Raichur. Little millet was cleaned and treated with IR heat at a feed rate of 500 kg/h and an IR power level of 5 kW, followed by dehusking using a commercial pneumatic rubber roll millet dehusker (Agrosaw, RB3, Haryana, India). For the storage study, untreated dehusked little millet (control) and little millet subjected to IR heat treatment followed by dehusking were packed in PET (400 µm) packaging material and stored under room temperature conditions for six months. The effect of IR heat treatment on the biochemical characteristics viz., proximate composition (moisture content, carbohydrate content, crude protein, crude fat, crude fibre and total ash) and anti-nutrients (phenols, tannins and phytic acid) were evaluated at 30 days intervals throughout the storage period by following the standard procedures as outlined in Table 1 (Meti *et al.*, 2024b)^[14]. All chemicals of analytical grade were purchased from M/s. Sigma-Aldrich, Bengaluru and M/s. Fisher Scientific, Bengaluru.

Table 1: Biochemical characteristics of the untreated dehusked and IR heat treated dehusked little millet

Particulars	References
Proximate composition	
Moisture content (% w.b.)	AOAC, 2016 (Method No.925.10) ^[1]
Carbohydrate (%)	AOAC, 2016 (Method No.975.14) ^[1]
Crude protein (%)	AOAC, 2016 (Method No.992.23) ^[1]
Crude fat (%)	AOAC, 2016 (Method No.920.39) ^[1]
Crude fibre (%)	AOAC, 2016 (Method No.962.09) ^[1]
Total ash (%)	AOAC, 2016 (Method No.923.03) ^[1]
Anti-nutrients	
Phenols (mg/g)	Malick and Singh (1980) ^[11]
Tannins (mg/g)	Price <i>et al.</i> (1978) ^[17]
Phytic acid (mg/g)	Wheeler and Ferrel (1971) ^[18]

3. Results and discussion

Proximate composition

Moisture content

The changes in moisture content of untreated dehusked (Lc) and IR heat treated dehusked little millet (Lt) during storage are presented in Fig. 1. It was observed that the initial moisture content for Lc and Lt was recorded at 11.24% (w.b.) and 9.12% (w.b.), respectively. The moisture content of Lc decreased to 11.01% (w.b.) at 120 days but increased to 11.21% (w.b.) at 180 days. Similarly, for Lt, the moisture content decreased to 8.90% (w.b.) at 120 days and increased

to 9.10% (w.b.) at 180 days. Significant differences in moisture content at 180 days are observed among the control and IR heat treated samples, which might be attributed to their initial moisture content. The fluctuations in moisture content recorded during the storage studies may be ascribed to variations in the environmental conditions within the storage area, such as temperature and humidity. Huang *et al.* (2021)^[7] also observed a reduction in moisture content for dehulled millets, from 13.27 to 12.63% and noted a similar trend in heat treated dehulled millets, where moisture content decreased from 12.97 to 11.77% over a 90 days period of storage.

Carbohydrate content

From the Fig. 2, it was observed that the initial carbohydrate content for Lc and Lt had been recorded at 72.37 and 71.96%, respectively. As the storage period progressed, the carbohydrate content of Lc and Lt decreased to 68.82 and 70.19%, respectively, at 180 days. A reduction in carbohydrate content was observed in the control samples compared to the IR heat treated dehusked samples, likely due to insect infestation and microbial activity in the controls. During storage, grains undergo respiration, breaking down carbohydrate content into simpler molecules like carbon dioxide and water while releasing energy. Higher temperatures speed up this process, leading to a reduction in carbohydrate content over time. Under heat stress, the extra energy required for metabolism comes from breaking down carbohydrate content like starch (Braganca *et al.*, 2020).

Crude protein

From the Fig. 3, it was noted that as the storage period progressed, the crude protein of Lc and Lt decreased from 10.64 to 9.87% and from 10.16 to 9.42%, respectively, over 180 days. No significant differences ($p > 0.05$) in crude protein were observed at 180 days between the control and IR heat treated dehusked samples. Huang *et al.* (2021)^[7] also reported a reduction in crude protein in dehulled millets, decreasing from 6.72 to 6.29% over a 90 days period.

Crude fat

The crude fat content of Lc decreased from 3.78 to 3.69%, while that of Lt decreased from 3.75 to 3.68%. During storage period, crude fat content did not differ significantly ($p > 0.05$) between the untreated and IR heat treated dehusked little millet samples (Fig. 4). The decrease in crude fat content during storage may be attributed to the hydrolytic activity of lipolytic enzymes produced by microorganisms associated with the grains, resulting in the breakdown of lipids. The findings align with those of Huang *et al.* (2021)^[7], who reported a reduction in crude fat in dehulled millets over a 90 days period, with levels decreasing from 2.93 to 2.72%.

Crude fibre

The changes in crude fibre content of untreated dehusked little millet (Lc) and IR heat treated dehusked little millet (Lt) during storage are presented in Fig. 5. The initial crude fibre content was 5.68% in Lc and 5.66% in Lt. During the storage period, these values gradually decreased to 5.37% and 5.42%, respectively. However, no statistically significant difference ($p > 0.05$) was observed between the

untreated and IR heat treated samples. The reduction in crude fibre content may be attributed to the enzymatic degradation of structural polysaccharides by microorganisms associated with the grains, particularly through the activity of cell wall-degrading enzymes such as cellulases. A similar reduction in crude fibre during storage was reported by Fagbohun and Oluwaniyi (2015) [6], who observed a decrease from 10.27% to 8.52% in sun-dried rice after five months of storage.

Total ash

From the Fig. 6, it was noted that as the storage period progressed, the total ash of Lc and Lt decreased from 1.50 to 1.47% and from 1.49 to 1.47%, respectively, over 180 days. The total ash content did not differ significantly ($p > 0.05$) between the untreated and IR heat treated samples. A reduction in total ash content during storage was reported by Huang *et al.* (2021) [7], who observed a reduction from 1.40 to 1.30% in dehulled millets after 90 days of storage.

Anti-nutrients

Phenols

The changes in total phenolic content of untreated dehulled little millet (Lc) and IR heat treated dehulled little millet (Lt) during storage are presented in Fig. 7. At the beginning of storage, the phenolic content was 4.71 mg/g in Lc and 4.62 mg/g in Lt. A gradual reduction was observed in both samples over the storage period, reaching 4.03 mg/g and 4.18 mg/g, respectively, after 180 days. However, the phenolic content remained statistically comparable ($p > 0.05$) between the untreated and IR heat treated samples. A similar reduction in total phenolic content during storage

was reported by Babiker *et al.* (2018) [2], who observed a decrease from 194.10 to 142.80 mg/100 g in the white pearl millet cultivar after two months of storage.

Tannins

The changes in tannin content of untreated dehulled little millet (Lc) and IR heat treated dehulled little millet (Lt) during storage are presented in Fig. 8. Over the storage period, tannin content reduced from 0.39 to 0.22 mg/g in Lc and from 0.33 to 0.21 mg/g in Lt. Despite this reduction, no statistically significant difference ($p > 0.05$) was observed between the untreated and IR heat treated samples. A similar decreasing trend in tannin content during storage was reported by Babiker *et al.* (2018) [2], who observed a reduction from 174.43 to 105.62 mg/100 g in the white pearl millet cultivar over 60 days of storage. The reduction in tannin levels may be attributed to enzymatic degradation and other biochemical reactions occurring during storage.

Phytic acid

The variation in phytic acid content of untreated dehulled little millet (Lc) and IR heat treated dehulled little millet (Lt) during storage is illustrated in Fig. 9. Throughout the storage period of 180 days, phytic acid content decreased from 7.37 to 6.28 mg/g in Lc and from 7.32 to 6.21 mg/g in Lt with no significant difference ($p > 0.05$) between the untreated and IR heat treated samples. A comparable reduction in phytic acid during storage was also reported by Babiker *et al.* (2018) [2], who observed a decrease from 77.59 to 66.54 mg/100 g in white pearl millet after 60 days of storage.

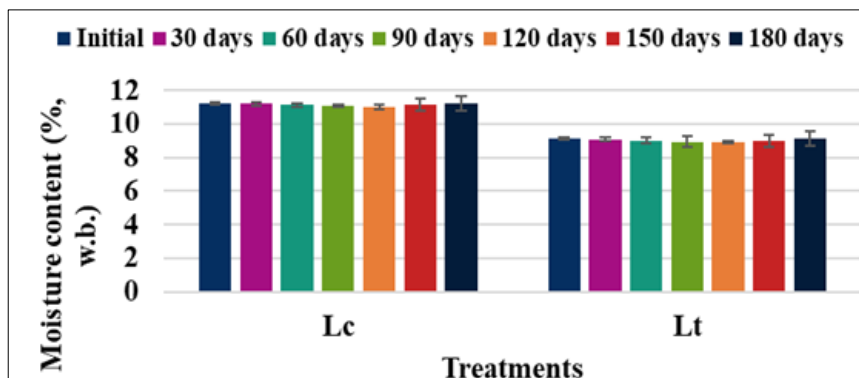


Fig 1: Moisture content of untreated dehulled little millet (Lc) and IR heat treated dehulled little millet (Lt) during storage-error bar indicates standard deviation

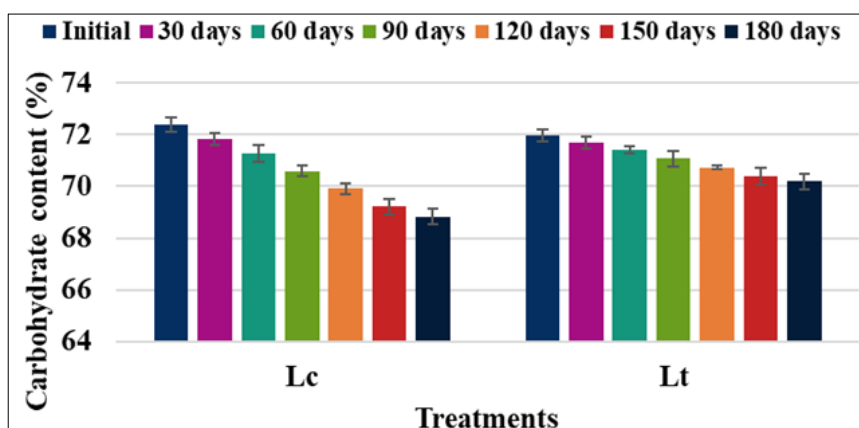


Fig 2: Carbohydrate content of untreated dehulled little millet (Lc) and IR heat treated dehulled little millet (Lt) during storage

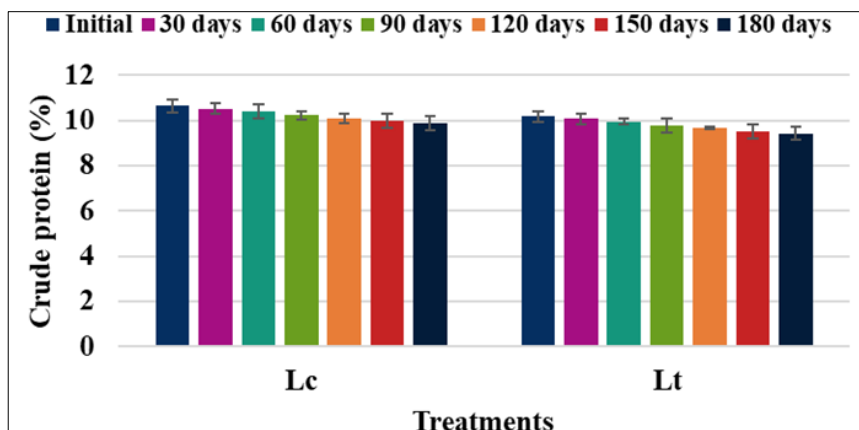


Fig 3: Crude protein content of untreated dehusked little millet (Lc) and IR heat treated dehusked little millet (Lt) during storage

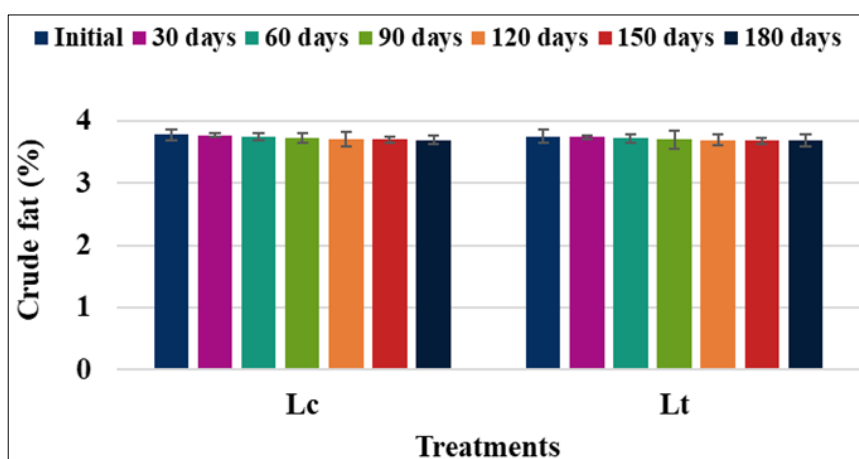


Fig 4: Crude fat content of untreated dehusked little millet (Lc) and IR heat treated dehusked little millet (Lt) during storage

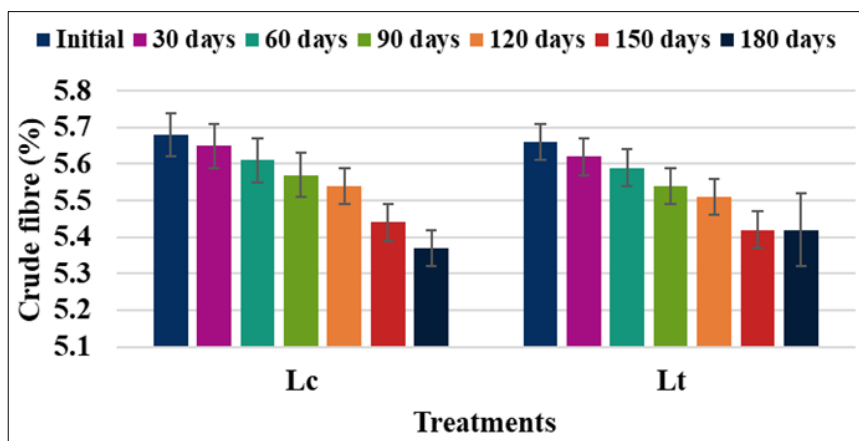


Fig 5: Crude fibre content of untreated dehusked little millet (Lc) and IR heat treated dehusked little millet (Lt) during storage

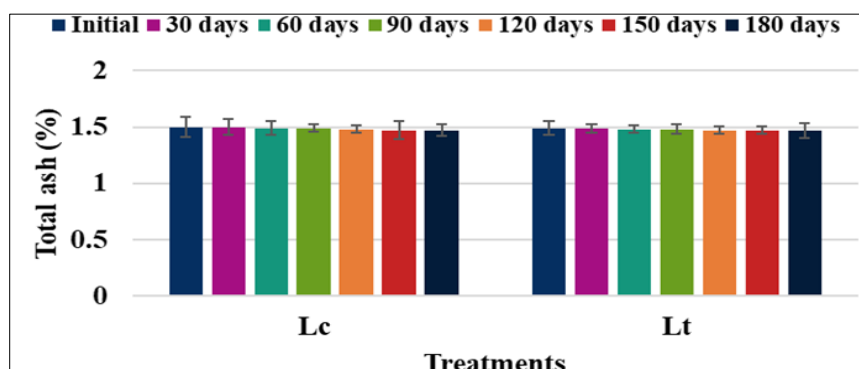


Fig 6: Total ash content of untreated dehusked little millet (Lc) and IR heat treated dehusked little millet (Lt) during storage

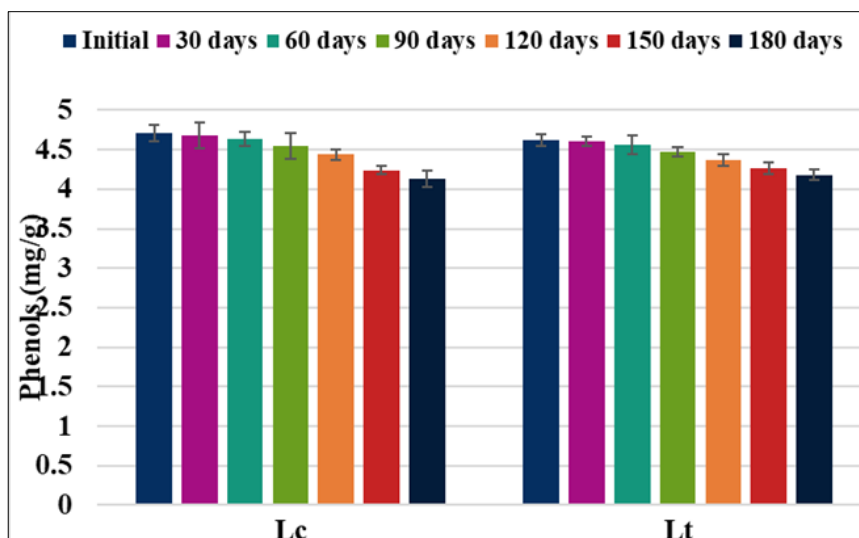


Fig 7: Phenols content of untreated dehusked little millet (Lc) and IR heat treated dehusked little millet (Lt) during storage

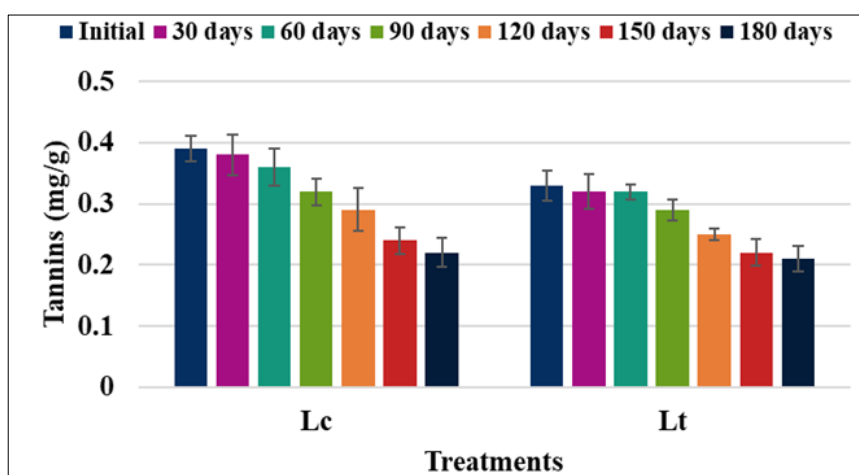


Fig 8: Tannins content of untreated dehusked little millet (Lc) and IR heat treated dehusked little millet (Lt) during storage

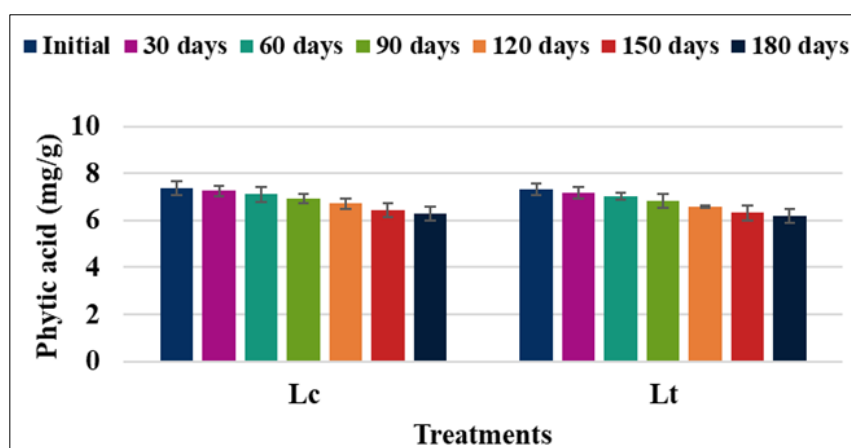


Fig 9: Phytic acid content of untreated dehusked little millet (Lc) and IR heat treated dehusked little millet (Lt) during storage

4. Conclusion

No significant differences were observed in the proximate composition and anti-nutritional factors between the untreated dehusked little millet and IR heat treated dehusked little millet over the storage period of 180 days. Therefore, Infra-red heat treatment effectively maintained the biochemical characteristics of dehusked little millet throughout storage, demonstrating its suitability as a pre-milling treatment for improving storage stability without adversely affecting its nutritional quality.

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Competing interests

Authors have declared that no competing interests exist.

Authors' Contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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