Letters in Applied Microbiology, 2026, 79(1), ovaf143
https://doi.org/10.1093/lambio/ovaf143
Advance access publication date: 12 December 2025
Research Article

LETTERS IN APPLIED MICROBIOLOGY
OXFORD UNIVERSITY PRESS

Brewery spent yeast medium for *Serratia* sp. bio-beads improves *Chenopodium quinoa* Willd. growth in the Northern Altiplano of Bolivia

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Abstract

Quinoa (*Chenopodium quinoa* Willd.) is a climate-resilient Andean crop with high nutritional value and strategic importance for food security in high-altitude regions. However, its productivity in low-input farming systems remains limited. This study developed scalable strategies for propagation and formulation of a *Serratia* sp. strain as a biofertilizer, using brewery spent yeast (BSY) as growth substrate. Microwave-assisted extraction (MAE) at 1200 W for 15 min significantly ($P \leq 0.05$) enhanced soluble protein release from BSY, and MAE-treated media with a C:N ratio of 24:1 supported optimal bacterial growth. Carrageenan-based bio-bead formulations produced at 40°C with 96 g L^{-1} carrageenan yielded the highest bacterial viability and moisture retention. In a field trial in the Bolivian Altiplano, bio-beads containing *Serratia* sp. applied at branching stage increased quinoa yield by up to 3.4-fold ($P \leq 0.01$) compared with the control. The formulation control also substantially improved yield (2.2-fold), indicating that both the carrier matrix and bacterial inoculation contributed to growth enhancement. These findings demonstrate the potential of biofertilizer technologies based on agri-food by-product valorization to improve crop performance under extreme and resource-limited agricultural conditions.

Impact Statement

This study presents a circular bioeconomy approach in Bolivia for quinoa production: transforming brewery spent yeast into a high-performance medium for *Serratia* bio-beads that increase quinoa yield 3.4-fold in the Bolivian Altiplano. By valorizing agro-industrial waste and employing microbial encapsulation, this strategy aligns with circular bioeconomy goals and provides a sustainable, low-input solution to improve food security in marginal farming systems.

Keywords: agricultural and industrial residues; carrageenan encapsulation; microwave-assisted extraction; plant growth-promoting rhizobacteria; quinoa stalks; sustainable agriculture

Introduction

Agriculture is essential for global food security; however, sustainable practices are increasingly required to reduce environmental impact (Mrabet 2023). Quinoa (*Chenopodium quinoa* Willd.) is a strategic crop due to its high nutritional value, broad environmental adaptability, and phenotypic and metabolic plasticity (Bazihizina et al. 2022, Yadav et al. 2023). Its wide genetic variability and nutritional composition have stimulated worldwide attention. Around 80% of global production remains in the Andean regions of Bolivia and Peru, although cultivation is expanding worldwide (Alandia et al. 2020, Pedrali et al. 2023). The Bolivian Altiplano is exposed to drought as well as being highly susceptible to erosion and soil degradation. Andean producers face critical challenges linked to market intensification, unsustainable agricultural practices, and reliance on complex export certification systems (Stöcker et al. 2024).

Plant growth-promoting rhizobacteria (PGPR) represent a sustainable strategy for improving crop performance in harsh environments by colonizing roots and enhancing survival, growth, and microbial competition (Olanrewaju et al. 2017). Well-studied genera include *Bacillus*, *Burkholderia*, *Paenibacillus*, *Serratia*, and *Pseudomonas* (Singh et al. 2022, Gonzales et al. 2024, Compant et al. 2025). *Serratia*, an endophytic diazotroph produces indole-3-acetic acid, cellulase, phosphatase, siderophores, and ACC deaminase (Gonzales et al. 2024, Kulkova et al. 2024). Despite their potential, commercial PGPR diversity remains limited, highlighting the need for safe, effective formulations (Hartmann and Six 2023).

Formulation is critical for PGPR scalability, as carrier materials affect microbial survival, soil persistence, and field efficacy (Negi et al. 2025). κ-Carrageenan offers advantages over other polymers due to its thermo-reversibility and low cost (Dong et al. 2021). Limited access to high-quality microbial

Received 14 October 2025; **revised** 9 December 2025; **accepted** 10 December 2025

media constrains bio-input scalability, particularly in developing countries. Circular bioeconomy approaches can valorize industrial by-products, such as brewery spent yeast (BSY), rich in proteins, vitamins, and bioactive compounds like β-glucans (Kandpal et al. 2024). BSY enhances microbial activity and biofertilizer development (Assandri et al. 2023). Efficient extraction, such as microwave-assisted extraction (MAE), enables rapid recovery of functional components without harsh chemicals, improving their suitability for PGPR media and biofertilizer formulations (Chemat et al. 2017, Farcas et al. 2022).

In this study, we hypothesized that MAE-treatment of BSY enhances release of growth-promoting factors to optimize the growth of the *Serratia* sp. strain IIFB006, previously reported to promote quinoa growth (Gonzales et al. 2024). We further hypothesized that carrageenan-encapsulated *Serratia* sp. strain IIFB006 can promote quinoa growth and yield. Optimal growth of *Serratia* sp. IIFB006 was achieved on BSY with a C:N ratio of 24:1, while the optimal condition for bio-bead production was 40°C and 96 g L^{-1} carrageenan concentration. Field application at the branching stage significantly increased quinoa growth and yield in the North Altiplano of Bolivia.

Materials and methods

Bacterial strain and maintenance

Serratia sp. strain IIFB006 isolated from the community of Canquella, Bolivia, and studied for its drought tolerance improvement in quinoa (Gonzales et al. 2024), was activated from a cryopreserved −80°C stock and grown in LP001 nutritive broth (NB; Oxoid, Hampshire, UK) for 48 hours (h) at 25°C. Subculture on nutritive agar (NA; prepared with 25 g L^{-1} of NB and 15 g L^{-1} agar) was performed to obtain individual colonies.

Collection of brewery-spent yeast

The seventh generation of *Saccharomyces cerevisiae* was collected in August 2023 from conical fermenters of the brewery "Compañía Cervecera Boliviana S.A." (Achocalla, La Paz, Bolivia). At sampling, the brewery reported a pH of 4.53–4.68 and degree Brix of 10.25 ± 0.02–10.45 ± 0.01. BSY was heat-inactivated at 84°C for 15 min (Varelas et al. 2016), moisture content of 78.9 ± 0.5%. The material was stored at −20°C before use.

Brewery yeast disruption

MAE was performed using a microwave extraction system (ETHOS X, Milestone SRL, Italy) at 2.45 GHz and 80°C. Seven hundred milliliter of heat-treated BSY (ht-BSY) was disrupted in a 2-L reactor at two power levels (1000 and 1200 W) and two time periods (10 and 15 min). The temperature sensor was set to open the reactor door when internal temperature fell below 45°C. After MAE, total soluble protein (Lowry et al. 1951), chemical oxygen demand (COD) (APHA 1985), and total nitrogen (Yuen and Pollard 1953) were quantified in duplicates. Untreated ht-BSY served as the control.

Alternative media for bacterial growth

Four culture media were formulated based on MAE-treated BSY or htBSY as carbon and nitrogen sources. Two C:N molar ratios (24:1 and 4:1) were established based on COD and total nitrogen measurements. For the C:N 24:1 formulations, 71.5 mL of either MAE-treated BSY (*Formulation 1*) or ht-BSY (*Formulation 2*) was added per liter of medium. A reference medium was prepared using glucose (20.85 g L^{-1}) as carbon source and Nutrient Broth (NB; 8 g L^{-1}) providing nitrogen and growth factors (*Referential medium 1)*. For the C:N 4:1 formulations, urea (2.65 g L^{-1}) was supplemented as an additional nitrogen source to either MAE-treated BSY (13.5 mL; *Formulation 3*) or ht-BSY (13.5 mL; *Formulation 4*). A standard NB medium (8 g L^{-1}) was used as *Referential medium 2*.

Fifty mL of each medium were prepared in 125 mL flask. For BSY formulations, stock solutions of urea (100 g L^{-1}; pH adjusted to 6.5 with 0.1 mol L^{-1} NaOH) and glucose (200 g L^{-1}) were used. The bacterial inoculum was prepared in NaCl (9 g L^{-1}) with $3{\cdot}10^8$ colony-forming units (CFU) mL^{-1} (1.0 McFarland). Media were inoculated in duplicate with 3% (v/v) inoculum, and uninoculated flasks served as abiotic controls. Cultures were incubated at 28 ± 2°C, with continuous shaking at 120 rpm. Two-milliliter samples were taken every 12 h for 72 h to monitor growth and pH. CFU were quantified by plating 10^{-3},10^{-4}, 10^{-6}, and 10^{-7} dilutions on NA. Plates were incubated at 20 ± 2°C for 2 days in darkness.

Formulation of bio-beads for field experiment

A reported carrageenan bio-beads formulation protocol (Gonzales et al. 2024) was optimized by testing two temperatures (40 and 80°C) and five carrageenan (MAPRIAL, Cochabamba, Bolivia) concentrations (in g L^{-1}): 16 (C1), 36 (C2), 56 (C3), 76 (C4), and 96 (C5), in duplicate. Fifty milliliters of each carrageenan solution were maintained at 40 or 80°C for 30 min. After cooling to 40°C, 50 mL of *Serratia* sp. suspension ($3{\cdot}10^8$ CFU mL^{-1}) was homogenized into each solution and maintained at 40°C before extrusion. Formulations were extruded using a peristaltic pump (Ecoline, Masterflex ISM 1089C) through 2.06-mm ID tubing onto a 1:1 (w/w) mixture of dry starch and ground quinoa stalks (45 μm), generating bio-beads.

Physicochemical analysis of bio-beads

Bio-beads were collected in 50 mL sterile plastic tubes and stored at 4°C before use. Moisture was determined in triplicate from 1 g of sample dried at 105°C for 24 h and kept in a desiccator before weighing. The diameter of 10 randomly selected beads was measured using a vernier, and the bead number was determined per gram of sample. Water absorption was measured by immersing 1 g of bio-bead in 200 mL of distilled water for 5 min, followed by brief drying and weighing (Pourjavadi et al. 2004). Organic carbon was quantified in 25 mg samples according to the Walkley and Black method (Baker 1936), total nitrogen was determined in 1 g of sample by the micro-Kjeldahl method (Yuen and Pollard 1953), and total assimilable phosphorus measured in 0.5 g of sample according to the Olsen method (Olsen 1954).

Field experimental design

A field trial was conducted on a 400 m^2 plot at Hilata Arriba community, La Paz, Bolivia (3937 m a.s.l.; 16°43′20.9"S, 68°19′25.6"W; Fig. 1). The plot remained fallow for three years, with potatoes as the previous crop. Treatments included a bacterial formulation (bio-beads with *Serratia* sp. IIFB006), formulation control (beads without bacteria), and a negative

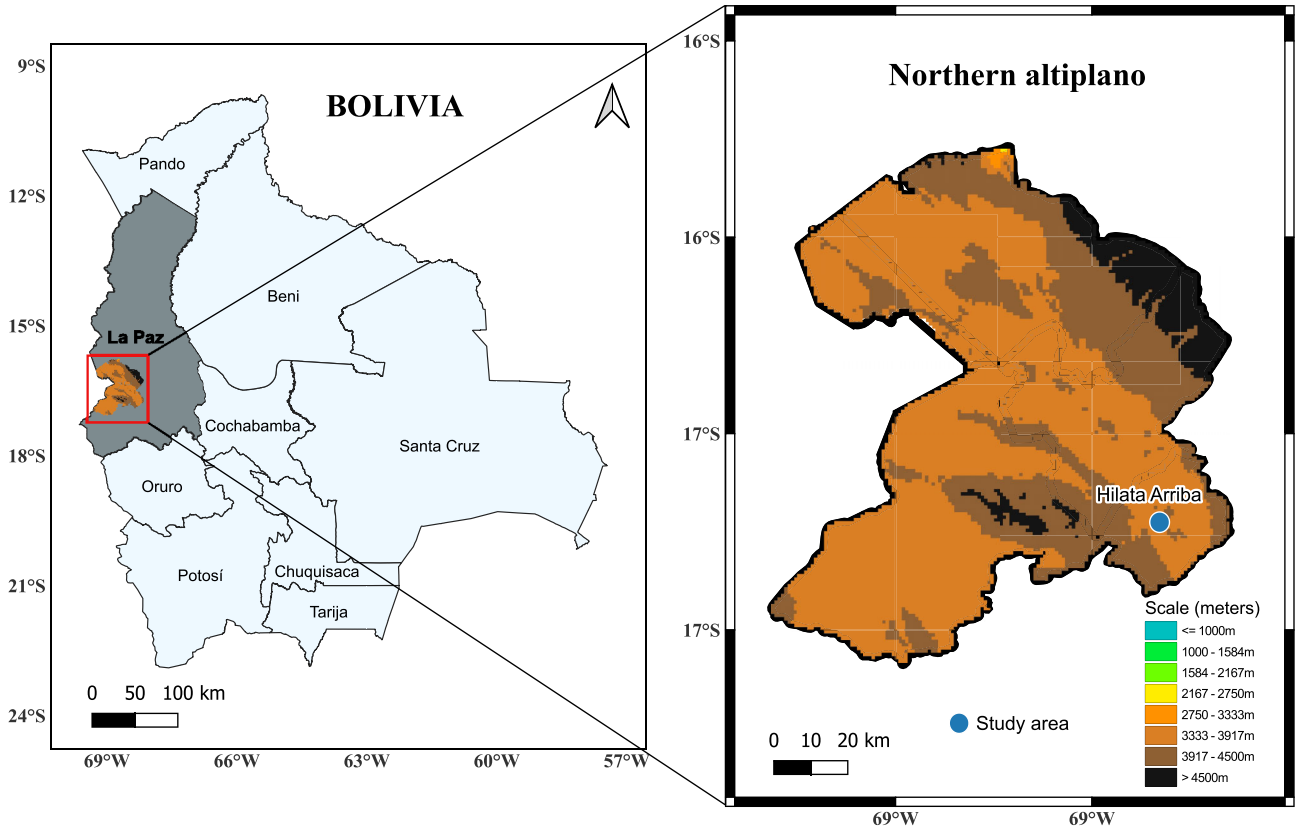

Figure 1. Study area of the field trial at the community of Hilata Arriba in the Northern Altiplano of Bolivia from 2023 to 2024. Geographical data were downloaded from DIVA-GIS (https://diva-gis.org/).

control. A randomized complete block design with four replicates (16.1 m^2 each) was used, with 1.6 m corridors and 1.0 m external borders. Soil preparation involved disc plowing (0.2 m depth, 0.8 m spacing). Quinoa (Jacha Grano) was sown at 10 kg ha^{-1} in December 2023 and irrigated once with groundwater (9 m^3 ha^{-1}) 24 days after sowing. At the four-leaf stage (day 48), plant density was adjusted to 130–150 plants per plot. On day 56, 1 g of bio-beads was applied to the topsoil around each plant. Plants were harvested at maturity (day 146), and plant length, panicle length, fresh weight, and grain yield (after 30 days drying in the dark) were recorded.

Soil analysis

Conductivity and pH were registered *in situ* using a digital multiparameter (Hanna, Rhode Island, USA). Samples of 1 kg were collected and placed in plastic bags before sowing and after harvesting. Organic carbon was measured according to the Walkley and Black method (Baker 1936), total nitrogen by the micro-Kjeldahl method (Yuen and Pollard 1953), and total assimilable phosphorus by the Olsen method (Olsen 1954), in duplicates. The color of dry soil was compared with the Munsell soil chart (Thompson et al. 2013), and texture (Bouyoucos 1962) using a soil hydrometer (ASTM, Minnesota, USA).

Results and discussion

Effect of MAE on BSY composition and *Serratia* growth

MAE significantly increased soluble protein extraction from BSY. After 10 min at 1000 and 1200 W, protein levels reached 24.2 ± 0.2 and 23.3 ± 0.9 mg g^{-1}, respectively, compared with 20.3 ± 0.9 mg g^{-1} in the control ($P \leq 0.05$). After 15 min, protein recovery increased to 26.0 ± 0.7 and 26.4 ± 0.1 mg g^{-1} at the same power levels ($P < 0.01$; Fig. 2). Total nitrogen (21.23 ± 0.3 g L^{-1}) and COD (514.78 ± 0.5 g L^{-1}) remained comparable between MAE-treated samples and the control, corresponding to a C:N ratio of 24:1. These results show that increasing MAE treatment time significantly enhanced protein yield from BSY, consistent with the extraction of carbohydrates from *Scenedesmus* sp., where a similar time was identified significant factor (Yirgu et al. 2021), but contrasting with microwave power effects described by Varghese and Pare (2019). The darker extract and sediment formation at 1200 W for 15 min likely indicate thermal degradation or aggregation of heat-sensitive compounds (Farcas et al. 2022), as prolonged exposure can promote protein crosslinking and reduce solubility (Deng et al. 2022, Wang et al. 2024).

BSY proteins have biotechnological potential and may serve as nutrient sources in microbial media (Gao et al. 2024). *Serratia* sp. strain IIFB006 showed higher biomass accumulation over 72 h in media with C:N 24:1 than in C:N 4:1 (Fig. 3). *Formulation 1* supported the highest biomass ($P \leq 0.05$) compared to formulations 2, 3, 4, *Referential medium 2*, performing similarly to *Referential medium 1* (Supplementary material 1). This growth suggests that MAE enhance the release of growth-supporting compounds from BSY, although only total carbon, nitrogen, and phosphorus were measured. Reported constituents of BSY (amino nitrogen compounds, B vitamins, folate) may support microbial metabolism (Jacob et al. 2019, Gao et al. 2024) and remain

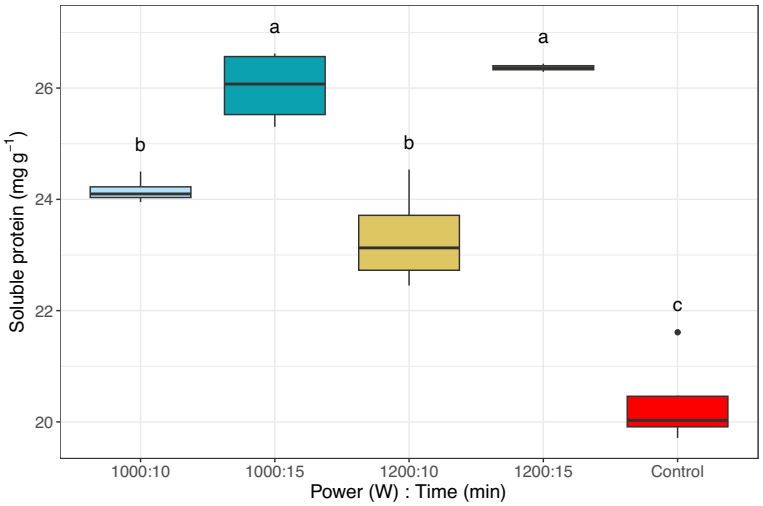

Figure 2. Soluble protein content in brewery spent yeast subjected to MAE at 1000 and 1200 W for 10 and 15 min. Different lowercase letters indicate significant differences between treatments (Tukey's post hoc test, $P \leq 0.05$).

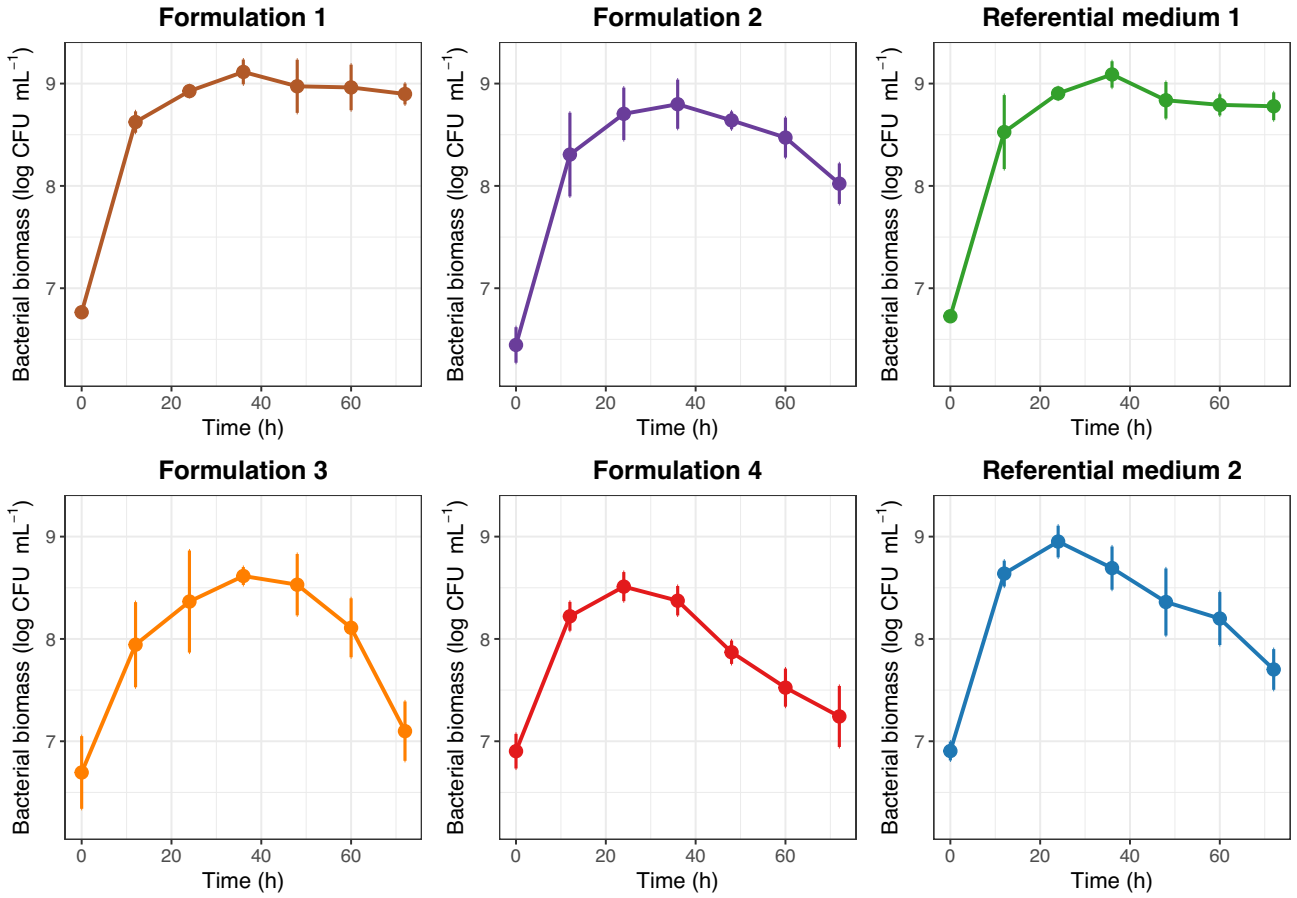

Figure 3. Bacterial growth in a referential and formulated media with carbon to nitrogen (C:N) ratios of 24:1 and 4:1. Average values are represented by dots, and error bars indicate standard deviation. Media with 24:1 C:N ratio: *Formulation 1:* MAE-treated BSY; *Formulation 2:* ht-BSY and *Referential medium 1:* Glucose-supplemented NB. Media with 4:1 C:N ratio: *Formulation 3:* MAE-treated BSY + urea; *Formulation 4:* ht-BSY + urea; *Referential medium 2:* NB.

hypothetical mechanisms. Consistent with our results, carbon and nitrogen are key determinants of microbial growth and critical for formulation (Masurekar 2008). *Formulation 1* maintained stable cell density during the stationary phase (36–72 h), unlike *Formulations 3* and *4*. Biomass reduction at C:N 4:1 may reflect insufficient carbon or nitrogen-induced substrate inhibition (Brown et al. 2022). The C:N ratio of 24:1 in BSY approximates the optimal 20:1 (or C:N:P 100:5:1) for aerobic microbial media (Hamza et al. 2019). Initial pH was 6.0 across treatments, except Formulations 3 and 4 (pH

5.0), shifting to alkaline conditions (pH 7.4–9.1) after 72 h (Supplementary Material 2).

Effect of temperature and carrageenan concentration on bio-beads

As shown in Table 1, both temperature and carrageenan concentration significantly affected bio-bead properties. At 40°C, increasing carrageenan concentration resulted in a linear increase in relative humidity from 23.5% (C2) to 40.1% (C4), with no further improvement at C5 (41.2%; $P \leq 0.05$). Total nitrogen content remained consistent, except for C1 (2093.7 mg kg^{-1}), which was significantly lower ($P \leq 0.05$). Bacterial biomass was initially similar across treatments, but after 72 h increased linearly from $2.5{\cdot}10^8$ CFU g^{-1} (C3) to $1.2{\cdot}10^9$ CFU g^{-1} (C5; $P \leq 0.05$). At 80°C, only formulation C1 could be produced, indicating thermal limitations at high temperature (Table 1).

Microorganism delivery systems depend on carrier formulation to sustain moisture and cell viability (Vejan et al. 2019). Our results highlight carrageenan concentration as a key determinant of moisture retention and bacterial biomass. Concentrations above 50 g L^{-1} can reduce solubility due to altered hydrogel mechanics (Horinaka et al. 2022), while adequate water availability supports microbial survival and controlled release (Kang et al. 2024). Processing at 40°C likely stabilized bio-beads at 96 g L^{-1} by promoting secure crosslinking; excessive heat disrupts κ-carrageenan stability (Horinaka and Hara 2025) and increases droplet aggregation, consistent with our observations at 80°C. Although storage was evaluated over a short period, carrageenan reportedly supports extended shelf life by forming compact cross-linked structures that protect microorganisms (Premjit et al. 2024), comparable to 3-year viability reported for alginate-based carriers (Trivedi and Pandey 2008).

Serratia sp. encapsulated in bio-beads enhances quinoa yield in the field

A limited number of studies have evaluated the field performance of endophytic *Serratia* formulated in carriers (El-Shamy et al. 2022, Gonzales et al. 2024). In our trial, *Serratia* sp. IIFB006 encapsulated in carrageenan bio-beads (C5) significantly increased seed yield, plant length, panicle length, and plant weight compared to both controls ($P \leq 0.05$), while formulation control also outperformed the negative control (Fig. 4). Seed yield reached 4188.2 ± 637.7 kg ha^{-1} with the bacterial formulation, representing a 3.4-fold increase over the negative control (1239 ± 346.4 kg ha^{-1}) and a 2.2-fold increase with the formulation control (2677.6 ± 383.8 kg ha^{-1}). These results align with previous observations where *Serratia* inoculation increased chickpea yield by 21.34% (Zaheer et al. 2016). Performance likely reflects interactions between formulation properties, soil nutrient dynamics, and multiple plant growth-promoting mechanisms attributed to *Serratia* (Gonzales et al. 2024, Kulkova et al. 2024). The increased quinoa growth in the formulation control suggests that the capsule material can stimulate the resident microbial community, providing a plant growth-promoting effect. Encapsulation improves microbial survival by protecting against drought and facilitating colonization (Gonzales et al. 2024). This is particularly advantageous in dry regions with low soil fertility. Post-harvest soil analyses (Table 2) showed an increase in organic carbon, total nitrogen, and assimilable phosphorus relative to

Table 1. Physicochemical properties and bacterial biomass of the designed bio-beads.

Carragenan concentration (g L^{-1})	Temperature (°C)	Moisture content (%)[1]	Water absorption (%)[1]	Diameter (mm)	Total organic carbon (g kg^{-1})	Total nitrogen (mg kg^{-1})	Total phosphorus (mg kg^{-1})	Bacterial biomass (cfu g^{-1}) Initial (0 h)	Final (72 h)
16	80	41.8 ± 0.4	74.7 ± 1.3	5.0 ± 1.0	275.7 ± 1.4	2166.5 ± 193.1	166.4 ± 9.5	$2.8{\cdot}10^8 \pm 0.0$	$1.2{\cdot}10^9 \pm 0.0$
16	40[2]	29.9 ± 0.1^c	78.6 ± 6.0^a	3.0 ± 1.0^a	275.7 ± 2.6^a	2093.7 ± 5.9^b	168.8 ± 12.9^a	$2.5{\cdot}10^8 \pm 0.1$	$6.8{\cdot}10^7 \pm 0.2^c$
36	40[2]	23.5 ± 1.1^d	77.8 ± 2.1^a	4.0 ± 1.0^a	267.8 ± 3.5^a	2689.7 ± 53.2^a	174.1 ± 5.4^a	$2.7{\cdot}10^8 \pm 0.0$	$5.2{\cdot}10^7 \pm 0.2^c$
56	40[2]	37.2 ± 0.6^b	72.5 ± 3.1^a	4.0 ± 1.0^a	293.1 ± 0.4^a	2653.8 ± 191.0^a	172.1 ± 6.6^a	$3.0{\cdot}10^8 \pm 0.0$	$2.5{\cdot}10^8 \pm 0.0^c$
76	40[2]	40.1 ± 0.1^a	87.7 ± 17.7^a	4.0 ± 1.0^a	291.7 ± 1.2^a	2723.1 ± 94.9^a	171.7 ± 8.1^a	$3.1{\cdot}10^8 \pm 0.0$	$6.2{\cdot}10^8 \pm 0.2^b$
96	40[2]	41.2 ± 0.3^a	71.9 ± 1.8^a	4.0 ± 1.0^a	288.6 ± 0.2^a	2699.0 ± 60.5^a	174.0 ± 5.9^a	$2.8{\cdot}10^8 \pm 0.1$	$1.2{\cdot}10^9 \pm 0.0^a$

Average values are presented as mean ± standard deviation, based on two replicates.
[1]Parameter measured at 72 h.
[2]Bio-bead properties at this temperature that do not share the same letter differ significantly ($P \leq 0.05$), according to Tukey's post hoc test.

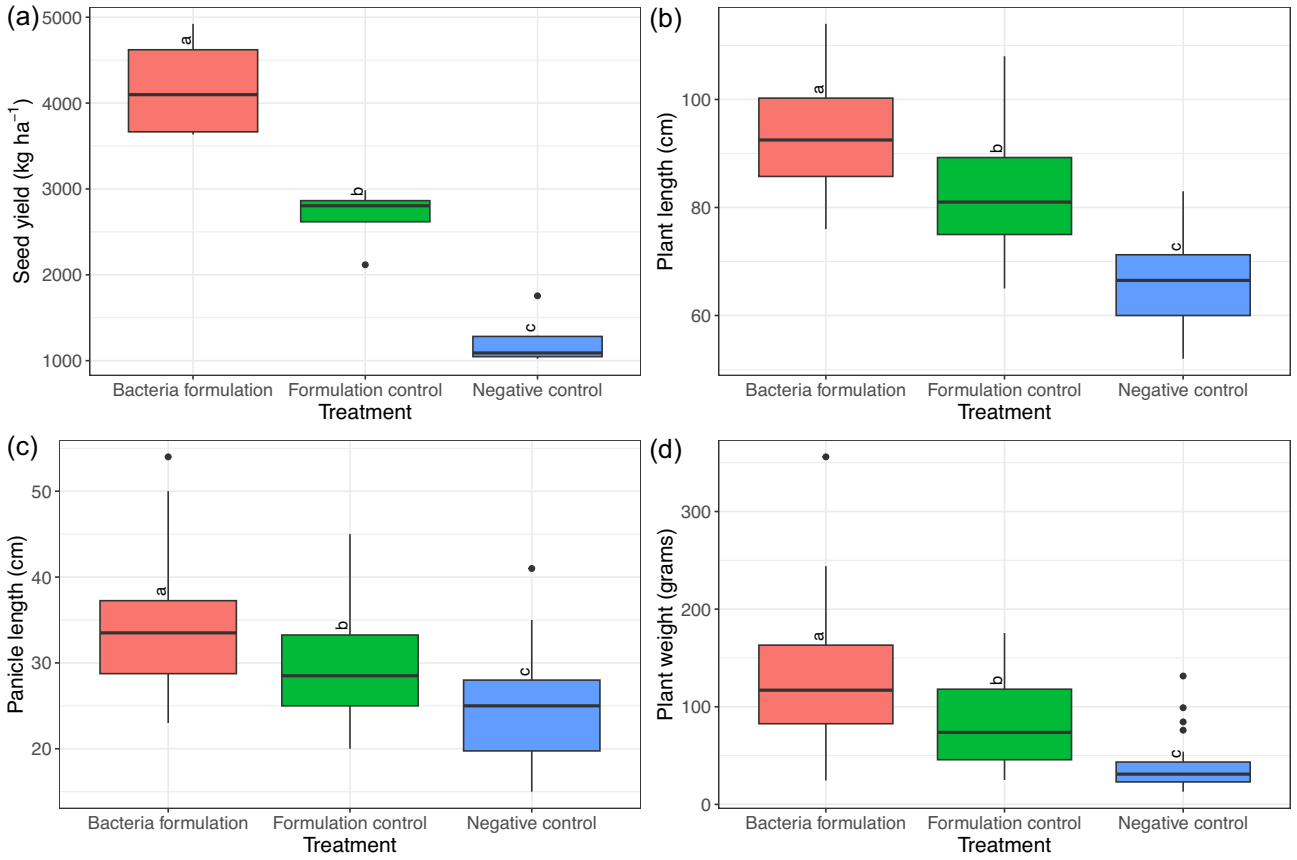

Figure 4. Quinoa phenotypic traits from a field trial in the northern Bolivian Altiplano. Seed yield (a), plant length (b), panicle length (c), and panicle weight (d) under the treatments: PGPR *Serratia* sp. strain IIFB006 formulated in bio-beads (bacteria formulation), bio-beads without PGPR (formulation control), and no treatment (negative control). Dots represent outliers; different lowercase letters indicate significant differences between treatments (Tukey's post hoc test, $P \leq 0.05$).

Table 2. Initial and final physicochemical properties of soil from the field trial in Hilata Arriba, La Paz, Bolivia, conducted between December 2023 and April 2024.

Soil parameter	Before sowing[1]	After harvest[1]
Sand (%)	68.0 ± 4.7	65.2 ± 3.8
Clay (%)	19.4 ± 5.6	17.4 ± 1.6
Silt (%)	12.6 ± 7.3	17.4 ± 5.3
Soil texture	Sandy loam	Sandy loam
Dry soil color	5 YR 4/4	5 YR 4/4
pH	8.1 ± 0.4	8.2 ± 0.4
Conductivity (mS m^{-1})	0.5 ± 0.3	0.3 ± 0.1
Organic carbon (mg kg^{-1})	5811.6 ± 1961.0	6331.5 ± 139.9
Total nitrogen (mg kg^{-1})	658.0 ± 129.5	819.0 ± 69.3
Total phosphorus (mg kg^{-1})	31.1 ± 1.0	40.4 ± 2.4

[1]Average values are presented as mean ± standard deviation, based on five replicates.

pre-sowing values, with only phosphorus showing a significant increase ($P \leq 0.05$). Enhanced phosphorus availability may result from microbial secretion of chelating substances or acidification processes (Della Monica et al. 2017). *Serratia* species can enhance phosphorus availability through the secretion of chelating substances that solubilize mineral phosphates (Osman et al. 2010). However, some *Serratia* species exhibit opportunistic pathogenicity (Trinh and Nguyen 2024) requiring biosafety evaluation. This study provides a proof of concept from a single site and season using one quinoa variety and small plot size. Field performance may vary with soil type, climate, altitude, or genotype. Multi-year, multi-site trials including additional quinoa varieties are required to validate consistency and scalability.

Conclusions

This study presents a biofertilizer strategy combining BSY valorization via MAE with carrageenan-based encapsulation of *Serratia* sp., which significantly increased quinoa yield under Bolivian Altiplano conditions. The approach is compatible with low-input systems due to its minimal resource demand and use of locally available by-products. It may also benefit other stress-tolerant Andean crops such as *Chenopodium pallidicaule* and *Amaranthus* spp. Scaling this technology could reduce reliance on synthetic inputs, improve nutrient cycling, and reinforce climate resilience in marginal areas. Future research should address multi-season performance, formulation stability, biosafety, and evaluation across diverse high-altitude cropping systems. Overall, this strategy offers a scalable contribution to regional agricultural sustainability within circular bioeconomy frameworks.

Acknowledgments

We thank the IIFB Pharmaceutical Chemistry Area for MAE support, the INIAF technicians for field assistance in Hilata

Arriba, and Martha Gonzales and her family for providing land and support during the trial.

Author contributions

Ximena Ramirez (Conceptualization [equal], Investigation [equal], Methodology [equal], Validation [equal], Writing – review & editing [equal]), Virginia Gonzales (Formal Analysis [equal], Investigation [equal], Project administration [supporting], Visualization [equal], Writing – original draft [lead]), Rogelio Maydana Apaza (Resources [equal], Writing – review & editing [equal]), Mukesh K Dubey (Project administration [equal], Supervision [equal], Writing – review & editing [equal]), Dan Funck Jensen (Project administration [equal], Supervision [equal], Writing – review & editing [equal]), Cristhian Carrasco (Methodology [equal], Supervision [equal], Writing – review & editing [equal]), Magnus Karlsson (Project administration [supporting], Supervision [equal], Writing – review & editing [lead]), and Carla Crespo (Conceptualization [equal], Funding acquisition [lead], Project administration [lead], Supervision [lead], Writing – review & editing [equal])

Supplementary data

Supplementary data is available at *LAMBIO Journal* online.

Conflict of interest : None declared.

Funding

Funding was provided by the Swedish International Development Cooperation Agency (SIDA) through the Science, Technology, and Innovation 2021–2025 program (project 54100087).

Data availability

The data underlying this article are available in the article and its online supplementary material.

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Received 14 October 2025; **revised** 9 December 2025; **accepted** 10 December 2025