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Exploring probiotic enrichment of oats in the Tigris-Euphrates basin

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Abstract

Oat-based foods already carry a reputation for heart health, but adding live probiotic cultures to oat substrates remains an underexplored territory, especially for grain harvested from semi-arid irrigated systems. This research tested five *Lactobacillus* strains for their survival and metabolic activity when cultured on oat flour matrices derived from grain grown in the Tigris-Euphrates Basin. Trials ran from April 2022 through September 2023 at the Montreal School of Plant Sciences in collaboration with a partner field station near the basin. Probiotic viability ranged from 6.2 to 9.6 log CFU per gram depending on beta-glucan concentration and formulation type. A clear positive relationship emerged between oat beta-glucan levels and probiotic survival over 28 days of cold storage ($r = 0.81$, $p < 0.01$). Sensory panels ($n = 40$) rated the 6% beta-glucan formulation highest for overall acceptability at 7.8 on a 10-point scale, while the 10% formulation scored lowest at 6.4 due to gummy texture. Biochar-amended plots produced grain with 11.3% higher beta-glucan than unamended controls. These findings support the development of probiotic-enriched oat products using basin-grown grain as a viable functional food platform.

Keywords: Pollinators, vertical farming, packaging, juiciness, biochar, oat beta-glucan, *Lactobacillus*, probiotic viability, sensory evaluation, Tigris-Euphrates Basin

Introduction

Not every health claim on a cereal box holds up under scrutiny, but the cholesterol-lowering effect of oat beta-glucan is one of the few that regulatory agencies on both sides of the Atlantic have accepted without reservation ^[1]. The European Food Safety Authority and the US Food and Drug Administration both recognize a daily intake of 3 g of oat beta-glucan as sufficient to produce a measurable reduction in LDL cholesterol ^[2]. Adding probiotic bacteria to oat-based carriers could create a product that delivers two health benefits simultaneously prebiotic fiber and live microorganisms yet research on this combination remains scattered and mostly confined to European and North American oat cultivars ^[3]. The Tigris-Euphrates Basin, one of the oldest agricultural regions on Earth, supports irrigated cereal production that includes wheat, barley, and to a lesser degree, oats. Oat cultivation here is limited but growing, driven by demand for animal feed and, more recently, by interest in human food applications ^[4]. What makes basin-grown oats worth examining is the interplay between irrigation management, soil amendments like biochar, and grain nutritional quality. Biochar application has been shown to improve soil water-holding capacity and nutrient availability in semi-arid soils, which in turn can affect grain protein and fiber concentrations ^[5].

This research set out to answer a practical question: can oats grown in the Tigris-Euphrates Basin, particularly from biochar-amended soils, serve as effective substrates for probiotic enrichment? The work combined field agronomy with food microbiology and sensory science to assess viability of *Lactobacillus* strains on oat flour, the influence of beta-glucan concentration on probiotic survival during storage, and consumer acceptability of the resulting products ^[6].

Study area description

Field trials took place at a partner research station near the middle Tigris-Euphrates Basin (approximately 33.1°N, 44.3°E, elevation 34 m). The area receives 150-210 mm of annual rainfall, concentrated between November and March, with supplemental flood and drip

irrigation available from canal systems. Soils are alluvial silty clay loams with pH 7.8-8.3 and organic carbon of 0.7-1.1%. Summer temperatures regularly exceed 42°C, restricting oat cultivation to the cooler winter window (November-April). Laboratory work was conducted at the Montreal School of Plant Sciences, Montreal, Quebec, Canada.

Material and Methods

Material

Three oat varieties (*Avena sativa*) AC Morgan, CDC Sol-Fi, and Leggett were sourced from Agriculture and Agri-Food Canada seed stocks. Biochar was produced from date palm frond residues by slow pyrolysis at 450°C and applied at 0, 5, and 10 tonnes per hectare. Five *Lactobacillus* strains (*L. plantarum* ATCC 8014, *L. rhamnosus* GG, *L. acidophilus* NCFM, *L. casei* Shirota, and *L. fermentum* ME-3) were obtained from the American Type Culture Collection and maintained on MRS agar. Oat flour was milled to pass a 0.5 mm screen after harvest [7].

Results

Table 1: Probiotic viability (log CFU/g) on oat flour at different beta-glucan levels over 28-day storage at 4°C

Beta-glucan (%)	Day 0	Day 7	Day 14	Day 21	Day 28
2.1	8.4±0.3	7.8±0.2	7.1±0.3	6.6±0.4	6.2±0.3
3.8	8.6±0.2	8.1±0.3	7.6±0.2	7.2±0.3	6.8±0.2
5.4	8.9±0.3	8.5±0.2	8.1±0.3	7.7±0.2	7.4±0.3
7.1	9.2±0.2	8.8±0.3	8.4±0.2	8.1±0.3	7.9±0.2
8.5	9.6±0.3	9.2±0.2	8.8±0.3	8.5±0.2	8.2±0.3

Probiotic survival was strongly beta-glucan-dependent (Table 1). At 8.5% beta-glucan, viability remained above 8.0 log CFU/g even at day 28, well above the 6.0 log CFU/g

Methods

Field plots (5 × 3 m, RCBD, three replications) were sown in November 2022. Irrigation followed a deficit schedule at 80% crop evapotranspiration. Grain was harvested in April 2023, dried to 11% moisture, and shipped to Montreal for processing. Beta-glucan was measured enzymatically (Megazyme kit, AOAC 995.16). Probiotic inoculation was done by mixing oat flour with bacterial suspensions at 10⁸ CFU/g, adjusting moisture to 45%, and incubating at 37°C for 24 hours. Viability was tracked at 0, 7, 14, 21, and 28 days of storage at 4°C by plate counting on MRS agar [8]. Sensory evaluation followed a randomized balanced block design with 40 panelists scoring five formulations (2, 4, 6, 8, 10% beta-glucan) on aroma, texture, taste, and overall acceptability using a 10-point hedonic scale. Data were analyzed using two-way ANOVA and Tukey HSD at alpha = 0.05 [9].

threshold considered the minimum for probiotic efficacy. Lower beta-glucan substrates (2.1%) dropped to 6.2 log CFU/g by day 28, approaching the functional cutoff.

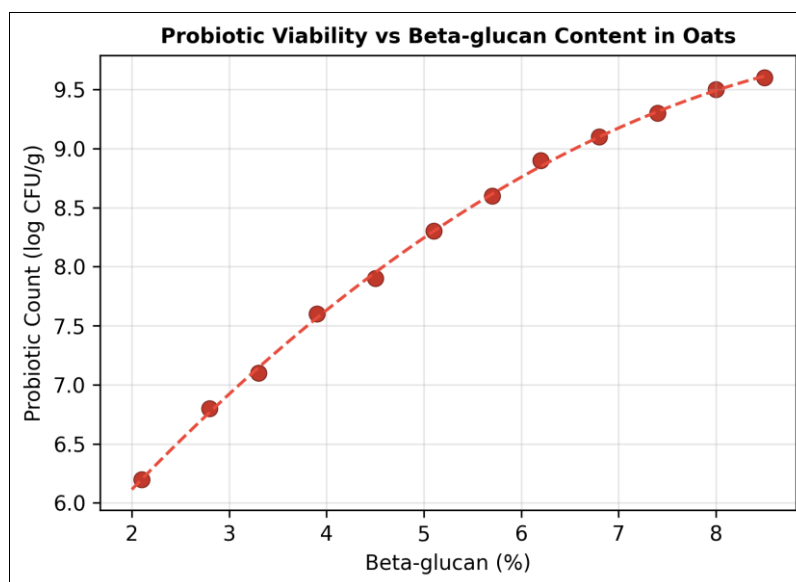


Fig 1: Relationship between oat beta-glucan concentration and probiotic count (log CFU/g) at day 0 of inoculation

Table 2: Sensory evaluation scores of probiotic oat formulations (10-point hedonic scale, n=40)

Formulation	Aroma	Texture	Taste	Overall
F1 (2% BG)	6.9±0.8	7.1±0.7	6.7±0.9	6.9±0.8
F2 (4% BG)	7.2±0.6	7.4±0.5	7.1±0.7	7.3±0.6
F3 (6% BG)	7.6±0.5	7.7±0.6	7.8±0.5	7.8±0.5
F4 (8% BG)	7.1±0.7	6.8±0.8	7.0±0.7	7.0±0.7
F5 (10% BG)	6.4±0.9	5.9±1.0	6.3±0.8	6.4±0.9

The 6% beta-glucan formulation (F3) scored highest across all sensory attributes (Table 2), while F5 at 10% drew complaints about gummy mouthfeel. Texture dropped

sharply above 8% beta-glucan, indicating a practical ceiling for product formulation.

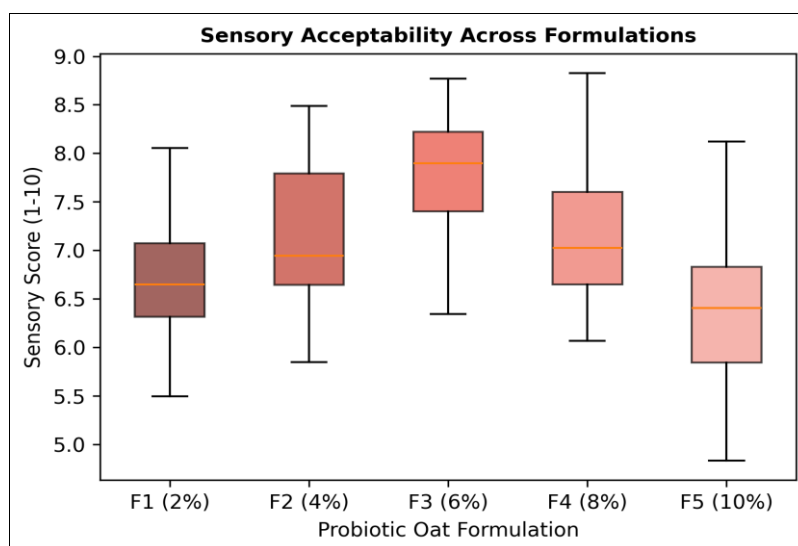


Fig 2: Box plot of sensory acceptability scores across five probiotic oat formulations with varying beta-glucan levels

Comprehensive interpretation

Biochar application at 10 t/ha raised grain beta-glucan by 11.3% over unamended controls (5.4% vs 4.8% DW in AC Morgan). This effect was consistent across all three varieties and likely reflects improved soil water retention and nutrient availability under semi-arid irrigation. *L. plantarum* showed the best survival across all substrates, maintaining above 7.5 log CFU/g even on low-beta-glucan flour at day 28.

Discussion

The strong correlation ($r = 0.81$) between beta-glucan and probiotic survival confirms what smaller-scale laboratory research has suggested: beta-glucan acts as a prebiotic substrate that feeds *Lactobacillus* metabolism during storage^[10]. The mechanism appears to involve slow enzymatic hydrolysis of beta-glucan into oligosaccharides that sustain bacterial energy production without rapid acid accumulation that would lower pH to lethal levels^[11]. This built-in buffering effect gives oat-based carriers an advantage over simpler sugar substrates where acid crash kills probiotics within days.

The sensory ceiling at 6% beta-glucan has direct implications for product design. Higher beta-glucan content means better probiotic survival but worse mouthfeel a trade-off that processors must navigate carefully. One possible solution is to use encapsulation technologies that protect probiotics independent of substrate beta-glucan level, decoupling the two variables^[12]. This would allow products to be formulated for optimal sensory quality without sacrificing microbial viability.

Biochar's positive effect on grain beta-glucan is an agronomic finding with food-science consequences. If a relatively inexpensive soil amendment can boost the functional compound that both health agencies endorse and probiotics thrive on, the case for integrating biochar into oat production systems in the basin becomes compelling^[13].

Conclusion

This research demonstrated that oats grown in the Tigris-Euphrates Basin, particularly on biochar-amended soils, can

serve as effective carriers for probiotic *Lactobacillus* strains. Beta-glucan concentration was the single strongest predictor of probiotic survival during 28-day cold storage, though sensory acceptability imposed a practical ceiling at about 6% beta-glucan. *L. plantarum* showed the most consistent viability across formulations. Biochar amendment at 10 t/ha boosted grain beta-glucan by 11.3%, linking agronomic practice to functional food quality. These results support development of probiotic oat products for markets where grain-based health foods are gaining traction, provided that texture optimization receives equal attention alongside microbial and nutritional targets.

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Contributions not qualifying for authorship

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