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Technofunctional properties of dextran produced by *Leuconostoc pseudomesenteroides* isolated from juçara palm fruit

Propriedades tecnofuncionais da dextrana produzida por *Leuconostoc pseudomesenteroides* isolado do fruto da palmeira juçara

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ABSTRACT

Juçara fruits (*Euterpe edulis* Martius), an important palm tree native to the Atlantic Forest ecosystem, exhibit a rich diversity of microorganisms, including lactic acid bacteria (LAB). LAB are highly capable of synthesizing exopolysaccharides (EPS), which are extracellular carbohydrate biopolymers with techno-functional properties, and consequently, wide applicability. In the present study, the technical-functional information of the dextran produced by *L. pseudomesenteroides* JF17 was obtained by determining its physicochemical, rheological, water-holding, oil-holding, and emulsifying properties. Dextran-JF17 mainly comprised carbohydrates (87.87% ± 1.45%, w/w), along with 48.86% ± 1.2% (w/w) of soluble fibers and a low protein content (2.98% ± 0.49%, w/w). The dextran exhibited high water-holding (470.89% ± 39.67%, w/v) and oil-holding (89.945% ± 4.16%, w/v) capacities, with values close to those reported for other microbial EPS. The dextran-JF17 solutions with concentrations 0.5%, 1.0%, and 2.0% (w/v) exhibited the typical pseudoplastic non-Newtonian fluid behavior. The emulsifying capacity of dextran-JF17 was higher (26.73 ± 0.31 mL of oil/g dextran) than that of guar gum (15.45 ± 1.33 mL oil/gum). In addition, dextran-JF17 presented an emulsifying activity of approximately 65% (w/v) within 24 h, indicating a strong emulsion stabilization capacity. Collectively, these results suggested that dextran-JF17 is a good candidate for application as a viscosity, stabilizing, and emulsifying agent in the food and pharmaceutical industries.

Index terms: Exopolysaccharide; biopolymer; emulsifier; rheology; *Euterpe edulis* martius.

RESUMO

Os frutos da juçara (*Euterpe edulis* Martius), importante palmeira nativa do ecossistema da Mata Atlântica, exibe uma rica diversidade de microrganismos, incluindo bactérias lácticas (LAB). As LAB são altamente capazes de sintetizar exopolissacarídeos (EPS), que são biopolímeros de carboidratos extracelulares com propriedades tecnofuncionais e, consequentemente, ampla aplicabilidade. No presente estudo, informações tecnofuncionais da dextrana produzida por *L. pseudomesenteroides* JF17 foram obtidas através da determinação de suas propriedades físico-químicas, reológicas, de retenção de água, de retenção de óleo e emulsificantes. A dextrana-JF17 era composta principalmente por carboidratos (87,87% ± 1,45%, p/p), juntamente com 48,86% ± 1,2% (p/p) de fibras solúveis e baixo teor de proteínas (2,98% ± 0,49%, p/p). A dextrana exibiu alta capacidade de retenção de água (470,89% ± 39,67%, v/v) e de retenção de óleo (89,945% ± 4,16%, v/v), com valores próximos aos relatados para outros EPS microbianos. As soluções de dextrana-JF17 com concentrações de 0,5%, 1,0% e 2,0% (p/v) exibiram o comportamento típico de fluido pseudoplástico não newtoniano. A capacidade emulsificante da dextrana-JF17 foi superior (26,73 ± 0,31 mL de óleo/g de dextrana) à da goma guar (15,45 ± 1,33 mL de óleo/goma). Além disso, a dextrana-JF17 apresentou uma atividade emulsificante de aproximadamente 65% (p/v) em 24 horas, indicando uma forte capacidade de estabilização de emulsões. Coletivamente, esses resultados sugerem que a dextrana-JF17 é uma boa candidata para aplicação como agente viscosificante, estabilizante e emulsificante nas indústrias alimentícia e farmacêutica.

Termos de Indexação: Exopolissacarídeo; biopolímero; emulsificante; reologia; *Euterpe edulis* Martius.

Introduction

Lactic acid bacteria (LAB) are present in ecosystems, where these microorganisms are in dynamic interactions with the members of both animal and plant kingdoms (George et al., 2018). Therefore, LAB occur naturally within plant and fruit microbiota, including those in juçara palm (*Euterpe edulis* Martius), which is a palm species native to the Atlantic Forest. *E. edulis* Martius is an important species for the ecosystem, and its fruits contribute to the sustainable application of the tree (Chaimsohn & Chiquetto, 2013). In addition, the microbiota of *E. edulis* Martius include LAB that are capable of producing a bioactive exopolysaccharide (EPS) (Farinazzo et al., 2020).

EPS is an extracellular long-chain biopolymer with a high molecular weight, produced during the metabolic process of

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microorganisms (Kaur & Dey, 2023). EPS exhibits distinct structural characteristics, conferring these biopolymers with specific physicochemical properties that define their technological applications, such as water-holding agents, gelling agents, emulsifiers, stabilizers, rheological and texture intensifiers, etc. (Hussain et al., 2017; Wang et al., 2021). The advantages of bacterial polysaccharides include higher water solubility compared to plant gums such as guar gum and locust bean gum, along with better viscosity and thickening, stabilizing, gelling, and emulsifying activities (Han et al., 2015).

EPS is reported as a promising agent for food development applications. For instance, Wang et al. (2021) reported that the addition of the EPS from *Leuconostoc mesenteroides* XR1 led to greater viscosity and elasticity in fermented milk. Nemati and Mozafarpour (2024) demonstrated that the addition of EPS from *L. mesenteroides* F27 improved the water-holding capacity and viscosity of yogurt, with the yogurt formulations containing EPS at the concentrations of 250 mg/L and 500 mg/L having better sensory acceptance, compared to the control without the addition of EPS.

Therefore, various EPS are known for their improvement effects on the techno-functional capabilities of food items in food and dairy industries (Daba, Elnahas, & Elkhateeb, 2021). Moreover, EPS are environmentally friendly, biodegradable, and non-toxic, and are, therefore, considered a sustainable alternative to their traditional synthetic counterparts (Mehta, Shukla, & Saraf, 2021). EPS has a significant commercial value in the global market and a promising potential for applications in various sectors other than the food industry (Gan et al., 2024).

LAB produce a wide variety of EPS with varied qualities. EPS synthesis has been studied in *Leuconostoc* (Xing et al., 2018), *Lactobacillus* (Dilna et al., 2015), and *Bifidobacterium* (Inturri et al., 2017). *Leuconostoc* species produce dextran, which is a homopolysaccharide containing just one monomer, i.e., glucose, connected through the linkages of either α-glucan with α-(1→6), mutan with α-(1→3), or alternan with α-(1→6) and α-(1→3) (Majumder & Goyal, 2009). In certain previous studies conducted by our research group, a microbial dextran produced by the *Leuconostoc pseudomesenteroides* JF17 strain isolated from juçara fruits was obtained and identified as an α-glucan with α-(1→6) linkages, excellent thermal stability, and a high antioxidant activity (Farinazzo et al., 2020).

To expand the perspectives of technological application and a possible future use in food, it is necessary to better study the recently discovered dextran produced by L. *pseudomesenteroides* JF17, isolated from juçara fruits in our previous studies (Farinazzo et al., 2020). The choice of this strain is mainly due to its high yield of 53.77 mg/mL, confirmed by the Luedeking-Piret model, which suggested an efficiency in the production of polysaccharides from the substrate of 17.85 ± 0.74 mg EPS/log CFU (Farinazzo et al., 2022).

Specifically, the physicochemical, rheological, water-holding, oil-holding, and emulsifying properties of this dextran from *L. pseudomesenteroides* JF17 were evaluated.

Material and Methods

Microorganism and culture conditions

Juçara pulp (fruit-to-sterile water ratio, 1:1) was added to De Man, Rogosa, and Sharpe (MRS) broth (Merck, Germany) followed by incubation at 25 °C for 48 h (Novatecnica® Incubator, Brazil). After this period, MRS agar plates (Merck, Germany) were used to inoculate the fermented sample at 30°C for 48 hours in anaerobic flasks containing GasPak (Oxoid). The 198 resulting isolated colonies were examined for their morphology. Among these colonies, those with the characteristics of lactic acid bacteria (LAB) were evaluated further for their exopolysaccharide (EPS) production capacity. The evaluation was conducted by inoculating the colonies on MRS agar medium supplemented with 10% (w/v) sucrose, followed by incubation at 30 °C for 48 h (Farinazzo et al., 2020). Among the colonies developed, three identical colonies with a mucoid appearance were selected and subjected to molecular characterization through 16S rRNA gene sequencing. The bacterium identified in the sequencing analysis was registered in GenBank under the title *L. pseudomesenteroides* JF17 (MN756802).

Production and purification of dextran from the *L. pseudomesenteroides* JF17 strain

The *L. pseudomesenteroides* JF17 strain isolated in the present study was cultured at its maximum yield, as described by Farinazzo et al. (2022). Briefly, the strain JF17 was cultured in a previously optimized EPS-production MRS broth (Merck, Germany) supplemented with 18% (w/v) sucrose, with an initial pH of 7.3, at 20 °C for 48 h under static conditions (Novatecnica® Incubator, Brazil). The culture was then stored at –80 °C in 20% (v/v) glycerol. Next, the obtained crude dextran was purified through freeze-drying in distilled water followed by dialysis against deionized water for 48 h using a 12 kDa cellulose membrane (Sigma). The water used in the dialysis was changed every 12 h. After the dialysis purification, the resulting purified dextran was lyophilized (Freeze-dried L101 – Liobras, Brazil). The resulting powdered form of the purified novel dextran from *L. pseudomesenteroides* JF17 was designated as dextran-JF17 and used in subsequent analyses (Dilna et al., 2015).

Physicochemical analysis of the novel dextran

The dextran-JF17 samples were evaluated for moisture, ash, protein, lipid, and dietary fiber contents the AOAC method (AOAC, 2000). The total carbohydrate content in dextran-JF17 was determined using the phenol–sulfuric acid method, with

glucose as the reference standard (Dubois et al., 1956). The color of this dextran was determined using a colorimeter (Minolta®, model CR400, Osaka, Japan). The pH of the 1% solution of this dextran was measured at 25 °C using a digital potentiometer (Hanna® instrument, Romania).

Rheological properties of the aqueous solution of dextran-JF17

The rheological behavior of dextran-JF17 was analyzed using a Brookfield digital rheometer (Brookfield DV-III, Stoughton, Massachusetts, USA) and Rheocalc V33 software (Brookfield, Middleboro, USA). The observed rheological properties of this dextran were then compared to those of commercial guar gum (Durga Enterprises, India), which has been approved in most regions across the world (Food and Agriculture Organization - FAO, 2008). Dynamic viscosity was measured at 25 °C under 40 to 100 rpm and SC4-31 spindle for dextran-JF17 at concentrations 0.5%, 1.0%, and 2.0% (w/v) and guar gum at the concentration of 0.5% (w/v). In addition, guar gum concentrations of 1.0% and 2.0% (w/v) were evaluated for dynamic viscosity at 25 °C under 4 to 10 rpm and SC4-25 spindle. The shear stress, shear rate, and apparent viscosity data were collected every 45 s, preceded by 45 s of stabilization (totaling 3 min). The consistency index (K) and the flow behavior index (n) were calculated based on the Ostwald-De-Waele model (Power Law) Equation 1.

$$\tau = K \cdot \gamma n \quad (1)$$

Water-holding and oil-holding capacities

The water-holding capacity (WHC) of dextran-JF17 as well as that of guar gum was determined using the method reported by Lobo et al. (2019). Dextran or guar gum (40 mg) was diluted in 2 mL of deionized water, followed by thorough mixing on a vortex mixer for 10 min for uniform dispersion. The resulting uniform dispersion was centrifuged at 16000 × g for 25 min, followed by the removal of the unbound water. The obtained pellet was then placed on a pre-weighed filter paper for water removal and drying. The filter paper was then weighed again, and the percentage WHC was calculated using Equation 2 below:

$$\text{WHC (\%)} = \frac{\text{Sample weight after water absorption (g)}}{\text{Initial biopolymer weight (g)}} \text{ x } 100 \quad (2)$$

The oil-holding capacity (OHC) was calculated for both samples using the method reported by Insulkar, Kerkar and Lele (2018). Soybean oil was used as the medium of dispersion.

Emulsifying capacity

The emulsifying capacity (EC) was determined according to the method reported by Gurov et al. (1983), with certain modifications. Dextran-JF17 or guar gum (1 g) was homogenized in 10 mL of distilled water, to which soybean oil (nonpolar phase) was added at a flow rate of 3.5 mL/min through titration followed by mixing at a speed of 6,000 rpm using an Ultra-Turrax® Tube Drive (IKA® Brazil) shaker. The phase inversion point was determined by recording the point of sharp fall in the electric conductivity of the sample. The emulsifying capacity was then calculated as the amount of emulsified oil per gram of the sample (mL/g).

Emulsifying activity

Briefly, 3 mL of soybean oil was added to 2 mL of the aqueous solution of dextran (1.0%, w/v) or gum in a test tube (100 mm x 13 mm), followed by stirring for 2 min at 50 Hz using a vortex (Labnet´s Vortex Mixer VX-200). The resulting mixture was then stored at 25 °C for different durations of 0, 1, 24, and 168 h. The emulsifying activity of each sample (EA_1, EA_{24}, and EA_{168}) was then calculated using Equation 3 (Yang et al., 2018) below:

$$\text{EA1, EA24, EA168 or EA360} = \left(\frac{\text{Emulsion volume}}{\text{Total volume}}\right) \text{ x } 100 \quad (3)$$

Optical microscope examination of the prepared emulsions

A 50 µL volume of each emulsion (dextran-JF17 or guar gum, 1.0% w/v) prepared freshly at zero storage time at 25 °C was examined and photographed under the 40× objective lens of a light microscope (K55-BA, Olen@ Brazil).

Statistical analysis

All result data were expressed as mean ± SD and analyzed statistically through a one-way ANOVA using the Statistica software (version 10.0). The differences between the means were detected by conducting Tukey's post-hoc test with a significance level of 5%.

Results and Discussion

Physicochemical analysis of dextran-JF17

After purification, the dextran produced by *L. pseudomesenteroides* JF17 had a relatively low moisture content of 5.63% ± 0.08% (w/w), which demonstrated the efficiency of the lyophilization process. The ash content (Table 1) in dextran-JF17 was 2.79% ± 0.00% (w/w). The protein content in dextran-JF17 (Table 1) was also low (1.98% ± 0.49% w/w), indicating the efficacy of the methods used for the preparation and purification of dextran-JF17 in the present study. The protein content was

close to the value reported for the EPS produced by *Bacillus amyloliquefaciens* LPL061 (1.9%) (Han et al., 2015) and lower than the values reported in studies on the EPS produced by *Lactobacillus helveticus* MB2-1 and *Mesorhizobium loti* Semia 816 (4.08% and 11.31%, respectively) (Li et al., 2014; De Oliveira Amaral, & Burkert, 2018). These differences were attributed to the different techniques used for the isolation and purification of EPS in different studies. No lipid content was detected in dextran-JF17, which reinforced the efficiency of the purification process adopted. In comparison, the protein content in commercial guar gum was determined to be 4.85% ± 0.34% (Liu et al., 2020), which was 2.4 times higher than that determined for dextran-JF17.

Table 1: Physical-chemical properties of the dextran-JF17 produced by *L. pseudomesenteroides* JF17.

Physical-chemical composition	Dextran-JF17 (Mean ± SD)
Moisture (%)	5.63 ± 0.08
Ash (%)	2.79 ± 0.00
Proteins (%)	1.98 ± 0.49
Lipids (%)	ND
Total carbohydrates (%)	87.87 ± 1.45
Total fiber (%)	52.90 ± 0.15
Soluble fiber (%)	48.86 ± 1.2
Insoluble fiber (%)	4.04 ± 0.98
pH (1% w/v, solution at 25 °C)	5.72 ± 0.15
Color: a*= redness	4.57 ± 0.37
b*= yellowness	18.94 ± 0.70
L*= Lightness	80.24 ± 1.07

Data are means ± SD of triplicates. ND, not detected.

The total carbohydrate content in dextran-JF17 was 87.87% ± 1.45% (w/w), comprising 52.90% ± 0.15% (w/w) of total fibers, 48.86% ± 1.2% (w/w) of soluble fibers, and 4.04% ± 0.98% of insoluble fibers (Table 1). The high content of soluble fibers was consistent with the ability of dextran-JF17 to dissolve in water due to its highly linear structure (Farinazzo et al., 2020). High carbohydrate content has also been reported for the EPS produced by LAB in several previous studies (Han et al., 2015; Trabelsi et al., 2018). Murwan, Abdelwahab and Sulafa (2012) have reported similar values (83.3%–87.5%) for carbohydrate content in guar gum, although the total fiber content reported was lower (1.4%–2.0%).

Further, the average pH of the 1% solution of dextran-JF17 at 25 °C was determined to be 5.72 ± 0.15. In addition, dextran-JF17 presented a high lightness value (L* = 80.24 ± 1.07), while the a* and b* values were determined to be 4.57 ± 0.37 and 18.94 ± 0.70, respectively (Table 1). These values corresponded to a yellowish color, and it was, therefore, understood that the incorporation of this dextran in food products could affect the color of the final product (Trabelsi et al., 2018).

Rheological properties

The viscosity versus shear curves (Figure 1) revealed that the viscosity of dextran-JF17 decreased as the shear rate increased. The highest viscosity values recorded for dextran-JF17 (106.48 mPa.s) were obtained at the lowest shear rate (13.6/s) at an aqueous concentration of 2.0% (w/v) (Figure 1a). Therefore, for all tested concentrations, the dextran solutions exhibited a non-Newtonian behavior corresponding to a pseudoplastic fluid, with the viscosity decreasing as the shear rate increased. The same characteristics were observed for guar gum (Figure 1b). The behavior of a polysaccharide in a solution generally corresponds to that of a pseudoplastic fluid (De Oliveira et al., 2018). Other authors have also reported that the dextrans produced by different microorganism species, such as *L. pseudomesenteroides* XG5, *Leuconostoc dextranicum* NRRL B-1146e, and *Leuconostoc citreum* BMS, exhibit a pseudoplastic behavior (Majumder, & Goyal, 2009; Zhou et al., 2018; Abid et al., 2021). In addition, the apparent viscosity decreased in the following order (Figure 1): 2.0% > 1.0% > 0.5% for guar gum and 2.0% > 1.0% > 0.5% for dextran-JF17. The increase in the polymer concentration could have led to the occurrence of intermolecular interaction, which might have limited the polymer chain arrangement and stretching, leading to the observed increase in the viscosity of the polymer (Freitas et al., 2009).

The Ostwald-De-Waele model (Power Law) is used widely to describe the rheological behavior of pseudoplastic fluids. The model parameters are presented in Table 2. Dextran-JF17 and commercial guar gum presented n values of less than 1 (range 0.45–0.95), confirming their pseudoplastic behavior. Moosavi-Nasab, Alahdad and Nazemi (2009) reported that the viscosity of the dextran produced by *L. mesenteroides* NRRL B512 at different concentrations decreased as the shear rate increased, which is a typical characteristic of a pseudoplastic fluid. In the same study, k was observed to increase from 16.82 ± 4.86 to 43.07 ± 5.46 with an increase in dextran concentration from 1.5% and 10% (w/v), respectively, which was consistent with the values obtained in the present study for dextran-JF17 (Table 2).

In the context of food product development, this pseudoplastic property of the dextran produced by *L. pseudomesenteroides* JF17 is important as it would confer good sensory effects during swallowing and food processing operations such as mixing and pumping. The polysaccharides exhibiting a pseudoplastic behavior are considered suitable for the manufacture of various food products, including sauces, dairy products, cakes, and salad dressing (Han et al., 2014).

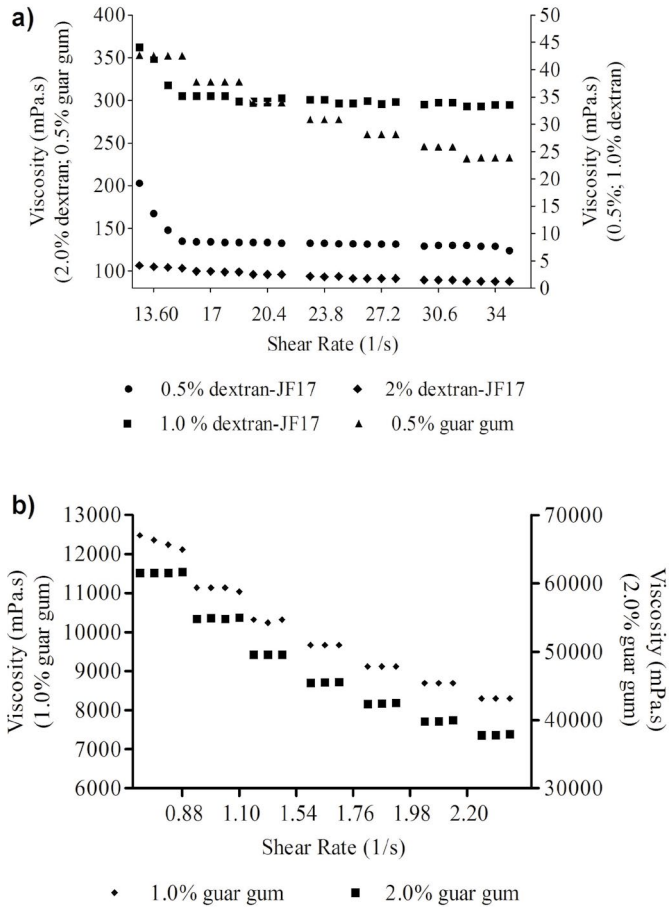

Figure 1: Viscosity as a function of the shear rate of aqueous solutions, including 0.5, 1.0, 2.0% dextran-JF17 and 0.5% commercial guar gum (A), and 1.0, 2.0% commercial guar gum (B).

Table 2: Effect of various concentrations of aqueous solutions of dextran-JF17 and commercial guar gum on the rheological parameters.

	Concentration (% w/v)	K (mPa)	N	(R^2)
Dextran-JF17	0.5	10.01	0.93	0.99
	1.0	39.79	0.95	0.99
	2.0	169.43	0.81	0.99
Guar gum	0.5	1156.80	0.55	0.99
	1.0	11581.00	0.56	0.98
	2.0	57470.00	0.45	0.98

Flow behavior index, n, and consistency index, K, were obtained by the Ostwald-de-Waele model.

Water-holding and oil-holding capacities

The WHC for dextran (470.89% ± 39.67%, w/v) was significantly higher ($p < 0.05$) compared to the WHC for guar gum (290.87% ± 9.62%, w/v) (Table 3). The WHC for dextran-JF17 was close to that reported previously for the dextrans produced by *Leuconostoc lactis* KC117496 (509.45% ± 28.59%) (Zhao et al., 2019) and *W. cibaria* JAG8 (352%) (Tingirikari, Kothari, & Goyal, 2014). The particle structure and the low moisture content of the polymer significantly influenced the hydrocolloid hydration properties. The high WHC of dextran-JF17 could be linked to the microstructure of the porous polymer, which enabled the retention of huge amounts of water molecules (Farinazzo et al., 2020). The above results indicated that dextran-JF17 had excellent hydrophilicity and water-holding capacity, demonstrating its promising potential in improving the textural and rheological properties of food products to which it would be added.

Table 3: Technical-functional properties of dextran-JF17 and commercial guar gum.

Properties	Dextran-JF17	Guar gum
Water holding capacity (%)	470.89 ± 39.67[a]	290.87 ± 9.62[b]
Oil holding capacity (%)	89.94 ± 4.16[a]	107.82 ± 11.80[a]
Emulsifying capacity (mL/g)	26.73 ± 0.31[a]	13.50 ± 1.52[b]

Data are means ± SD of triplicates and alphabet letters indicate the same letters in the same line are not statistically significantly different according to Turkey test *($p < 0.05$).

Further, the oil-holding capacity of dextran-JF17 was remarkable (89.95% ± 4.16%, w/v), with the value presenting no significant difference ($p < 0.05$) compared to the value recorded for guar gum (107.82% ± 11.80%, w/v) (Table 3). The OHC of dextran-JF17 was higher than the values reported for the EPS produced by *Weissella confusa* KR780676 (5.1%) (Devi, Kavitake, & Shetty, 2016) and *Lactobacillus* sp. Ca6 (15.9%) (Trabelsi et al., 2018). OHC reflects the degree of adsorption of organic compounds on the surface of a substrate and is, therefore, closely related to the porosity of the fiber structure as opposed to the affinity of the fiber molecule for oil (Biswas et al., 2009). Since the OHC of dextran-JF17 did not differ statistically from that of the already commercialized guar gum, dextran-JF17 could also be a suitable candidate for application in food industry applications that involve the structural interaction and absorption by fat, mainly favoring flavor retention, better palatability, and prolonged shelf-life (Gan et al., 2020).

Emulsifying capacity (EC)

The dextran-JF17 produced by *L. pseudomesenteroides* exhibited an EC of 26.73 ± 0.31 mL of oil/g dextran (Table 3), which was significantly higher ($p < 0.05$) than that determined for commercial guar gum (13.50 ± 1.52 mL oil/gum). It is known that microbial and vegetable gums, as well as certain vegetable and animal proteins, exhibit a lipid emulsifying effect. Guar

gum, although having a highly hydrophilic nature, reduces the surface tension of water and adsorbs on the oil-water interfaces, reducing the interfacial tension (Garti & Reichman, 1994).

The EC of an EPS is attributable to certain functional groups present in the biopolymer, which provide hydrophobicity to the EPS and thereby contribute to its EC (Maalej et al., 2016). Dextran-JF17 comprises glucose molecules and could, therefore, be considered a polar structure (Farinazzo et al., 2020). Moreover, it contained approximately 3% protein, possibly linked covalently to this molecular arrangement, and this might have contributed to its EC. The EC of other commercial gums, such as acacia gum with an EC of 30.5 ± 2.86 mL oil/gum, is attributed to a glycoprotein fraction (data not presented). The hydrophobic portion adsorbs strongly on the surface of the oil droplets, while the hydrophilic branches limit the aggregation and coalescence of the droplets due to steric and/or repulsive electrostatic forces (Desplanques et al., 2012).

Emulsifying activity (EA)

The emulsions of dextran-JF17 or guar gum (1%, w/v) in soybean oil were evaluated for their stability after 1 h, 24 h, and 168 h, and the results are presented in Table 4. Dextran-JF17 exhibited an EA of 65.44% ± 1.09% (w/v) after 1 h, and a significant decline ($p < 0.05$) was observed only after 168 h of storage at 25 °C (52.64% ± 0.65%, w/v). The same trend was observed for guar gum, for which a significant decline was noted after 168 h (43.44% ± 1.41%, w/v).

Table 4: Emulsification activity of dextran-JF17 or commercial guar gum (1.0% w/v, aqueous solutions) at different time intervals.

Emulsification activity (%)	Dextran-JF17	Guar gum
EA_0	100 ± 0.00^{Aa}	100 ± 0.00^{Aa}
EA_1	65.44 ± 1.09^{Ba}	58.50 ± 2.12^{Ba}
EA_{24}	62.27 ± 0.56^{Ba}	56.20 ± 2.40^{Ba}
EA_{168}	52.64 ± 0.65^{Ca}	43.44 ± 1.41^{Cb}

The mean values (± SD) of triplicates within the same column that do not share the same common capital letters differ significantly ($p < 0.05$). Different lowercase letters indicated significant differences in data on one line ($p < 0.05$). EA_0, EA_1, EA_{24} and EA_{168}: emulsification index after 0, 1, 24 and 168 h, respectively.

After 1 h of emulsification, the dextran-JF17 emulsion maintained greater stability (65.44% ± 1.0%) compared to the guar gum emulsion (58.50% ± 2.12%). The same trend was observed at 24 h and 186 h. Therefore, it was inferred that dextran-JF17 was more stable than guar gum, as the latter exhibited a lower EA at 168 h of storage. According to this finding, dextran-JF17 could be considered a good emulsion stabilizing agent.

The EA of an EPS reflects its ability to retain a hydrocarbon emulsion in water. In addition to increasing the emulsion viscosity, EPS may form a stable emulsion film and prevent the emulsion droplets from coalescing (Paximada et al., 2016). If a compound is to be considered a stable emulsifier, it must retain at least 50% of the emulsion after its formation (Gan et al., 2020).

Further, the surface activity of the polysaccharides that contributes to the stability of the emulsion is attributable to the presence of hydrophobic groups to facilitate molecular bonding at the oil interface and the ability of the chain structure to sterically stabilize the oil droplets (Kpodo et al., 2020). The dextrans produced by *L. pseudomesenteroides* YF32 and *Leuconostoc citreum* N21 were also reported to exhibit emulsifying activities of 67.25% and 66.7% ± 0.87%, respectively, in sunflower oil, after 1 h, with a slight decline to 64.36% and 63.4% ± 0.92% noted after 24 h (Yang et al., 2018; Yang et al., 2019). These values are close to those recorded in the present study.

Microscope examination of emulsions

The typical micrographs for the emulsions prepared using dextran-JF17 and commercial guar gum are depicted in Figure 2. Smaller, more dense, compact, and uniformly distributed droplets were observed in the emulsion prepared using dextran-JF17, while larger droplets were observed in the emulsion prepared using guar gum. The size of the emulsion droplet is considered an important parameter determining the physical stability of the emulsion in terms of flocculation and the creaminess rate of the emulsion (Kim, Morr, & Schenz, 1996).

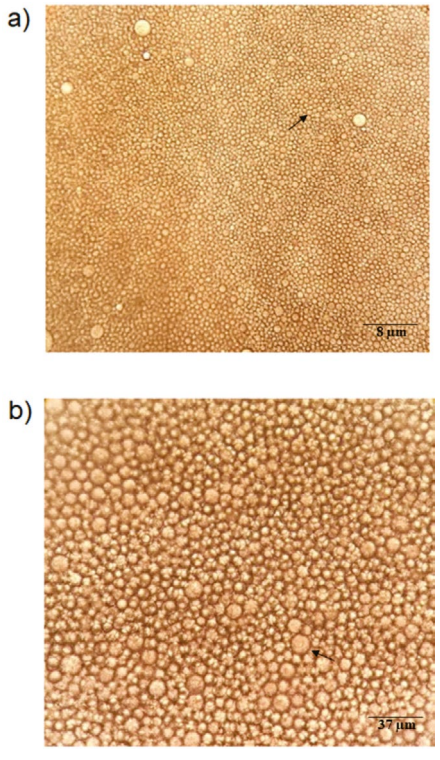

Figure 2: Photomicrographs of emulsions prepared with 1% (w/v) of (a) dextran-JF17, (b) guar gum (40 ×) with soybean oil.

The emulsion prepared using dextran had a smaller droplet size, with most particles smaller than 8 µm in size (Figure 2a), while the sizes of droplets in the guar gum emulsion varied from 10 to 37 µm (Figure 2b). Han et al. (2015) reported that the drops of an emulsion prepared using 1% EPS from *Bacillus amyloliquefaciens* LPL061 were smaller than 7 µm in size, compared to the guar gum emulsion drops that ranged from 1 to 58 µm in size. Smaller drops of oil result in a more stable emulsion (Liu et al., 2023). Therefore, the results obtained in the present study demonstrated that dextran-JF17 has the potential to be used as an emulsifier in the food industry.

Conclusions

Dextran-JF17 consisted mainly of carbohydrates, with approximately 40% soluble fiber. It had a high water and oil retention capacity, close to that reported by other microbial EPS. It maintained EA close to 65% and was able to stabilize the emulsions in soybean oil. Furthermore, it presented lower viscosity compared to guar gum, with non-Newtonian pseudoplastic behavior. Dextran-JF17 is recommended as a biopolymer for viscosity, stabilization, and emulsification in food. Future studies should explore its potential in different food formulations.

Author Contribution

Conceptual idea: Farinazzo, F.S.; Methodology design: Farinazzo, F.S.; Data collection: Farinazzo, F.S.; Data analysis and interpretation: Farinazzo, F.S. Carlos Fernandes, M.T.; Ishii Mauro, C.S.; and Writing and editing: Farinazzo, F.S; Carlos Fernandes, M.T.; Ishii Mauro, C.S.; Morais Filho, M. L.; Supervision: Garcia, S.; Prudencio, S.P.; Visualization: Farinazzo, F.S; Morais Filho, M. L.; Garcia, S.; Prudencio, S.P.

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