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RESEARCH ARTICLE

Commercial Tara Protein: Functional properties and use to stabilize sacha inchi oil emulsions obtained by ultrasound

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Abstract

Commercial tara protein (CTP) and sacha inchi oil are promising Peruvian products for forming food emulsions. The present work aimed (1) to characterize the functional properties of CTP as a new protein source (water and oil absorption, foam, and gelling capacity) and (2) to deepen the CTP to form sacha inchi oil emulsions. The CTP (2%, 4%, 6%) and oil concentration (15%, 20% and 25%) were evaluated for rotor-stator (RS) emulsion production. Final emulsions (RS-US) were produced with RS emulsions added with 2% tara gum and ultrasound homogenization at 75% power amplitude for 3 min. Emulsions were analyzed according to gravitational stability, droplet size, and optical microscopy. The results showed that the CTP presented a centesimal composition of 6.03% moisture, 45.16% proteins, 12.32% lipids, 2.49% fiber, 6.04% ashes, and 27.96% carbohydrates. CTP had a greater oil absorption (2.1442 ±0.26 g/g solids) than water absorption (1.8201 ±0.02 g/g solids), did not present foam formation, and the least gelation concentration was 18%. RS-US emulsions prepared with 25% oil and 2% or 4% protein had greater stability against the creaming index and phase separation during 4h, despite emulsion prepared with 15% oil presenting the lowest mean droplet size. In conclusion, the results show that commercial tara protein effectively prepared emulsions with a combined method (rotor-stator, ultrasound, and tara gum).

Keywords: *Caesalpinia spinosa*; *Plukenetia volubilis* L.; stability; droplet size; tara seed germ; tara protein.

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1. Introducción

Tara (*Caesalpina spinosa*) is a tree of Andean origin widely cultivated in Peru. This legume grows at an altitude of between 500 and 3,200 m in places with moderate rainfall and temperatures between 12 and 24 °C (De La Torre, 2018). The industry's interest in this tree lies in the use of its fruits, which are flattened and indehiscent pods of orange color and a size of 8 to 10 cm long and 2 cm wide (Pino et al., 2013). In the pods, there are round dark brown seeds, which represent 38% of the pod. Already, the ground seedless pods (tara powder) are mainly used in the tanning, alcohol, paints, pharmacy, and cosmetics industries (De La Torre, 2018).

The main product of Tara's industrial interest is in the seed's endosperm, which is Tara gum. A food hydrocolloid (E417) is highly sought for its rheological characteristics, generating high viscosity and thickening power at low concentrations. This behavior is due to its chemical structure of the galactomannan type, which is very similar to locusta gum and has technological properties similar to xanthan gum (Ahmad et al., 2019). This gum has been widely studied in recent years, such as a stabilizer for emulsions (Vélez-Erazo et al., 2020), gels (Ingrassia et al., 2019; Zhang et al., 2019), gluten-free bread (Vidaurre-Ruiz et al., 2019), and biofilms (Liu et al., 2020), among other applications.

Additionally, the seed germ is rich in protein content (Fierro et al., 2024), generating a new protein source as a by-product of the processing of this tree in the production of its gum. Notably, there needs to be more information found in the literature based on this protein source, generating interest in studying its functional properties, such as water or oil retention and the ability to form foams, gels, or emulsions.

On the other hand, the sacha inchi (*Plukenetia volubilis* L.) is also mainly native to the Peruvian jungle, growing in tropical forests between 200 to 1500 m altitude, with temperatures between 10 to 37 °C and with rainfall between 850 to 1000 mm al year (Goyal et al., 2022). Oil is the main product of this plant, which has generated great interest in the international market due to its chemical composition and potential health benefits. In the seed, the oil is found in a concentration between 41% - 54% (Otálora et al., 2020), mainly composed of mono- and polyunsaturated fatty acids (MUFA and PUFA, respectively). Silva et al. (2019) report that sacha inchi oil is mainly composed of oleic acid (14.65%), linoleic acid (42.5%), and linoleic acid (30.75%). The presence of high concentrations of the latter fatty acid is what makes sacha inchi oil so desirable on the market. It also contains micronutrients such as phytosterols, tocopherols, and phenolic compounds (Fanali et al., 2011), which is why its consumption is beneficial for health as it helps in the control of diseases such as obesity, diabetes, coronary and neurodegenerative diseases.

However, these types of oils are susceptible to oxidative deterioration, which generates unpleasant odors and flavors (Augustin et al., 2006). Additionally, it is chemically incompatible when incorporated into applications related to aqueous systems. Microencapsulation can be used to avoid or delay this process and transport the oil in aqueous systems. This technology protects different food or functional components, such as fatty acids, from various processing and storage factors, such as light, air, or humidity. It also masks taste, aroma, and unpleasant flavors while maintaining quality (Alarcón et al., 2020; Choudhury et al., 2021). Currently, research has been reported on obtaining stable emulsions of sacha inchi oil using different emulsifiers and stabilizers (Silva et al., 2019; Vicente et al., 2018).

In the oils microencapsulation, one of the most critical processes is emulsification, where the use of ultrasound has aroused great interest in recent years because the good stability of the emulsion is related to the size of the drop formed, representing a critical parameter in encapsulation efficiency (Rodea-González et al., 2012). For this reason, along with the technology selection, wall materials that are suitable for the design of emulsions must be chosen.

Proteins have good emulsifying properties that allow them to stabilize and prevent the lipid and aqueous phases from separating (Chang & Nickerson, 2018). In this sense, currently, vegetable proteins (e.g., oilseeds, legumes, and cereals) are being used more as emulsifying material because they have a lower degree of allergens, there is also a wide variety of sources, and they have a lower cost (Nesterenko et al., 2013). This is the case of Tara. However, until now, no research has been reported on using tara protein (CTP) as a stabilizer in emulsion formation.

For all the above, the objective of this research was to characterize the functional properties of the commercial tara protein or tara seed germ, studying its ability to obtain sacha inchi oil emulsions through ultrasound in more depth.

2. Methodology

2.1. Materials

Sacha inchi oil was obtained from Shanantina (Lamas, San Martin, Peru) and commercial tara protein (CTP) was obtained from tara germ and was purchase from Molinos Asociados SAC (Lima, Peru). Distilled water was used in all analysis.

2.2. Sample characterization

Commercial tara protein was characterized in terms of water content, ashes, lipids and protein content by the methods 966.02, 923.03, 920.39 and 920.87 of the Association of Official Analytical Chemists (AOAC) (AOAC, 2006). Carbohydrates were quantified by subtraction.

2.3. Functional properties

Water and oil absorption capacities

0.25 g of CTP was placed in a 50 mL centrifuge tube. Subsequently, 10 mL of distilled water for water absorption capacity (WAC) or sacha inchi oil for oil absorption capacity (OAC) was added. Centrifuge tubes were shake in a vortex (Heidolph, Germany) for 10 s every 5 min for 30 min. After the stirring time, samples were centrifuged (Centrifuge 5702, Eppendorf, Germany), at 1000 g for 15 min. The supernatant was then separated, and the tube was weighed along. For the OAC case, the tube was placed upside down for 10 min before weighing it. WAC and OAC were calculated according to equation 1 and were expressed in g of absorbed water/g of dry matter and g of absorbed oil/g of dry matter (Stone et al., 2015).

$$WAC\ or\ OAC\ (\%) = \frac{weight\ gained\ by\ the\ CTP}{original\ sample\ weight} \times 100 \quad [1]$$

Foam stability

CTP solutions were prepared at 0.05%, 1.0% and 2.0% (w/w) and hydrated for 2 hours in a magnetic stirrer (C-MAG HS 7, IKA, Germany). Then, 25 mL of the solutions were placed in 50 mL centrifuge tubes and homogenized in a Ultraturrax® (IKA®-Werke GmbH & Co. KG, Germany) at 8,000 rpm for 5 min. Subsequently, the solution was transferred to 50 mL graduated cylinders. Foam volume was measured immediately after being placed in the test tube and after 30 min. Foam stability (FS) were carried out through equation 2 (Lam et al., 2017).

$$FS\ (\%) = \frac{foam\ volume\ after\ 30\ min}{initial\ foam\ volume} \times\ 100 \quad [2]$$

Gelling properties

Boye et al. (2010) method was used with modifications. 20 g dispersions of CTP were prepared at 3%, 6%, 9%, 12%, 15%, 18% and 21%, which were stirred (C-MAG HS 7 magnetic stirrer, IKA, Germany) for 1 hour to obtain a homogeneous mixture. Then, 5 g of the dispersion were weighed into 15 mL falcon tubes and subsequently placed in a water bath (Aqualine AL 18, LAUDA, Germany) at 90 ºC for 30 minutes. Once the time was up, samples were cooled in an ice bath for a period of 5 minutes. The least gelation concentration was determined when a semi-solid remained adhered to the bottom of the tube.

2.4. Emulsifying properties

Preparation of protein solution

CTP dispersions were prepared at 2%, 4% and 6% (w/w) and stirred for 20 hours to ensure hydration (C-MAG HS 7 magnetic stirrer, IKA). Samples were placed in falcon tubes to be centrifuged at 4000 rpm for 15 minutes (Centrifuge 5702, Eppendorf, Germany). Supernatant was removed and placed in beakers to form emulsions.

Coarse emulsion (RS emulsions)

To prepare the RS emulsions, the method of Vélez-Erazo et al. (2018) was followed with modifications. Oil in water emulsions were formed using the previously prepared CTP solutions with sacha inchi oil (SIO) at 15%, 20% and 25%. Emulsions were homogenized with rotor-stator device Ultraturrax® (IKA®-Werke GmbH & Co. KG, Germany) at 8,000 rpm while the oil was added in the form of a thread; later, the speed was increased to 12,000 rpm for a period of 5 minutes.

Final emulsions (RS-US emulsions)

75% of the RS emulsion was mixed with 25% of tara gum dispersion (2.0% w/w), and the RS-US emulsion was subjected to sonication during 3 min at 75% of power amplitude (Ultrasound, Branson 250, USA, probe (Ø = 12.5 mm)). After obtaining both types of emulsions (RS and RS-US), the respective characterizations were carried out.

2.5. Emulsions characterization

Emulsion stability

Creaming index (CI) was evaluated as described by Taha et al. (2018) with certain modifications. Emulsions were placed in graduated cylinders of 50 and 100 mL, subsequently sealed and kept at room temperature. CI was calculated by time periods (30 min, 1, 4 and 24 hours) using equation 3 (CI: Creaming index, Vo: Initial emulsion, V: Volume of the upper phase).

$$CI\ (\%) = \frac{V}{V_0} \times 100 \quad [3]$$

Optical microscopy

Emulsion drops were placed on a glass slide and covered with coverslips. After this, their microstructure was observed under a microscope (Eclipse E200, Nikon Instruments Inc., USA), at 40x of magnification. The images were taken by the camera integrated into the microscope using the Motic Images Plus 2.0 software.

Droplet size

With the help of ImageJ software, the area (S) of 400 drops was measured and subsequently the calculation of the theoretical average diameter ($D_{[Th]}$) was carried out with equation 4 (Saout et al., 1999).

$$D_{[Th]} = \sqrt{4S/\pi} \quad [4]$$

2.6. Statistical analysis

All experiments had 2 experimental and 3 analytical repetitions, which were evaluated by analysis of variance (ANOVA). The results obtained were statistically analyzed using Minitab software (Minitab 17, United States). Next, the averages were compared using the Tukey test; for differences, significance was considered at 5%.

3. Results and discussion

3.1. Proximal composition

The proximal composition of CTP is presented in Table 1. Moisture, fat, protein and ash represented 6.03%, 12.32%, 45.16%, and 6.04% respectively. These values are similar to those reported in previous data (Del Re-Jimenez & Amado, 1989; Fierro et al., 2024), who found a humidity between 4.2% - 6.24%, a fat content between 13.5% - 13.93%, protein content between 41.6% – 54.32%, and ash content of 6.30%.

When compared with carob germ flour, another legume used to produce locust bean gum, it is observed that it has more protein than CTP (59.5%), but less fat, while moisture and ash are similar (Dakia et al., 2007). On the other hand, Silva et al. (2015) reported for pajuro seed flour, a species belonging to the Fabaceae family like tara, from different regions, lower values than those reported for tara, with protein ranging between 21.7 and 24.2%, a humidity of 9.47 and 9.13%, fat 3.01 and 2.71%, and ashes 2.69 and 2.71%.

Table 1
Proximal composition of Commercial Tara Protein (CTP)

Compound	Values
Moisture (%)	6.03 ± 0.23
Protein (%)	45.16 ± 0.06
Lipids (%)	12.32 ± 0.03
Ash (%)	6.04 ± 0.19
Carbohydrates (%)[a]	36.48 ± 0.52
Crude fiber (%)	2.49 ± 0.02

[a] Carbohydrate content was determined by difference from total composition.

3.2. Functional properties

3.2.1. Water and oil absorption capacities

Water and oil absorption capacities were evaluated after decantation of water and oil that was absorbed, where the results indicated that the CTP absorbed 2.14 ±0.26 g of oil for each gram of dry matter, while it absorbed 1.82±0.02 g of water for each gram of dry matter. This indicates that the protein flour has a greater affinity for oil than for water. Lafarga et al. (2018) reported 2.33 ± 0.12 and 2.69 ± 0.32 g of water or oil per g of isolated Ganxet bean protein concentrate, respectively. The value obtained in OAC is similar, but in the case of WAC it is higher than that found in the tara protein. On the other hand, the values obtained in this work are higher than those reported for red lentils with 1.90 ± 0.01 and 1.23 ± 0.01 g of water or oil respectively (Stone et al., 2019). Since this protein flour is marketed for use in the food sector, these two properties are of great importance, because both are indicators for determining whether its addition and use in different food products is feasible (Santana et al., 2017).

3.2.2. Foam stability

To analyze the foaming property of tara protein flour, three different percentages were used: 0.05%, 1.0% and 2.0%. Foaming was not observed in any of these percentages, indicating that tara protein flour does not have this capacity. Foam formation depends on several factors, such as concentration, protein solubility, the presence of lipids, and the degree of protein denaturation. In this case, two factors were identified that could have prevented foam formation: the high percentage of fat that this protein flour has (Table 1) and the low concentrations used in the analyzes, since the optimal concentrations for the formation of foam in proteins range between 2% and 8% (Damodaran, 1996; Santos Teixeira, 2009).

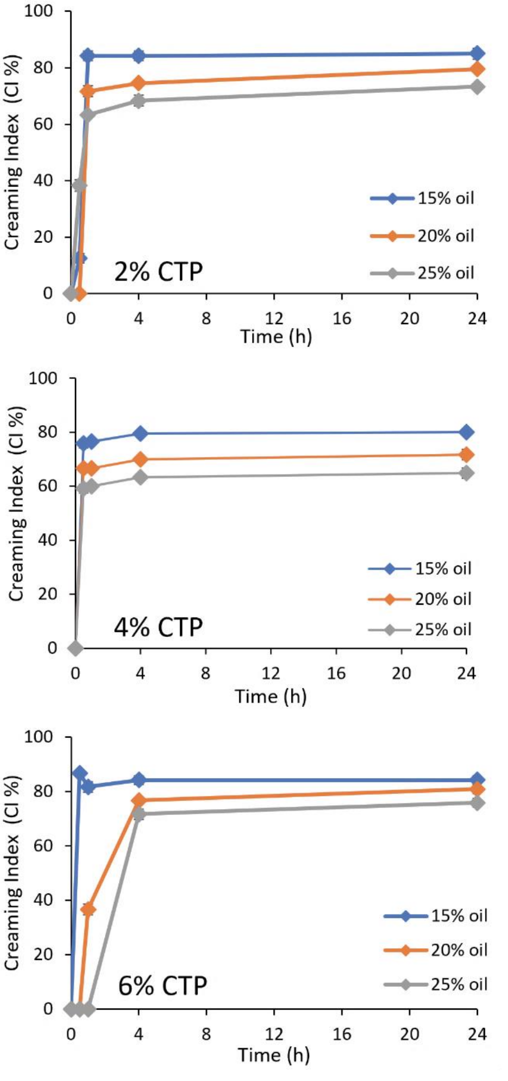

Figure 1. Creaming index of rotor-stator (RS) emulsions stabilized by commercial tara protein (CTP) at different CTP and chia oil concentrations.

3.2.3. Gelling properties

In this work, the gelation capacity of tara protein flour at different concentrations was evaluated. It was observed that the least gelation concentrations were 18% and 21%, which formed consistent and strong gels. On the contrary, concentrations of 3%, 6% and 9% failed to form gels, while those at 12% and 15% formed weak and viscous gels. These results agree with those reported by Dakhili et al. (2019), who indicated that the formation of gels depends on several factors such as heat, pH and enzymatic action.

On the other hand, *Cajanus Cajan* L. Millsp is a legume with high protein content. García et al. (2012) found that *Cajanus Cajan* L. Millsp flour required a minimum gelation concentration of 10%, lower than that of CTP. This difference could be due to the method of obtaining the flours, since the tara protein flour was obtained only by selection and grinding, while the *Cajanus Cajan* L. Millsp flour was subjected to a previous cooking process at 98 ºC followed by drying and grinding.

3.3. Coarse emulsion (RS emulsion) characterization

3.3.1. Emulsion stability

After evaluating the emulsions for the established time, the creaming index (CI) was calculated, and the results are shown in Figure 1 and Table 2. Table 2 shows the four-hour CI; this time was chosen to present the mean values of CI after the most stable emulsion became unstable. It was observed that all RS emulsions were unstable for a short period of time. Emulsions with 2% and 4% CTP had the highest CI in the first hour of evaluation, showing phase separation after 30 minutes. On the other hand, the CI decreased with increasing oil percentages. Only the emulsions with 6% protein emulsion and 25% oil remained stable for 1hour.

Table 2
Creaming index (CI) at 4h of stability and Mean droplet size ($D_{[th]}$) of RS emulsions

CTP	Oil	CI at 4h (%)	($D_{[th]}$) (µm)
2%	15%	84.17 ± 1.67 ^{Aa}	8.68 ± 5.88 ^{Bc}
	20%	74.58 ± 0.83 ^{Bb}	13.14 ± 10.34 ^{Ba}
	25%	68.33 ± 1.93 ^{Bc}	10.59 ± 9.36 ^{Bb}
4%	15%	79.58 ± 0.83 ^{Ba}	8.51 ± 6.53 ^{Bb}
	20%	70.00 ± 0.00 ^{Cb}	10.96 ± 8.35 ^{Ca}
	25%	63.35 ± 0.00 ^{Cc}	8.81 ± 7.28 ^{Cb}
6%	15%	84.17 ± 1.67 ^{Aa}	12.92 ± 12.43 ^{Ab}
	20%	76.67 ± 0.00 ^{Ab}	15.90 ± 11.38 ^{Aa}
	25%	71.67 ± 1.93 ^{Ac}	12.29 ± 12.79 ^{Ab}

CTP: commercial tara protein. RS: rotor-stator. Different letters indicate significant differences ($p < 0.05$). Capital letters: differentiate different percentages of protein. Lowercase letters: difference between different percentages of oil.

Some authors report low emulsion stability when formed only by the rotor-stator. Gomes and Kurozawa (2020) reported the formation of a creaming phase during the first hours of storage of emulsions stabilized by hydrolyzed rice protein. It is known that this method of emulsion formation produces systems with large droplet sizes, which promotes flocculation and subsequent coalescence of the droplets.

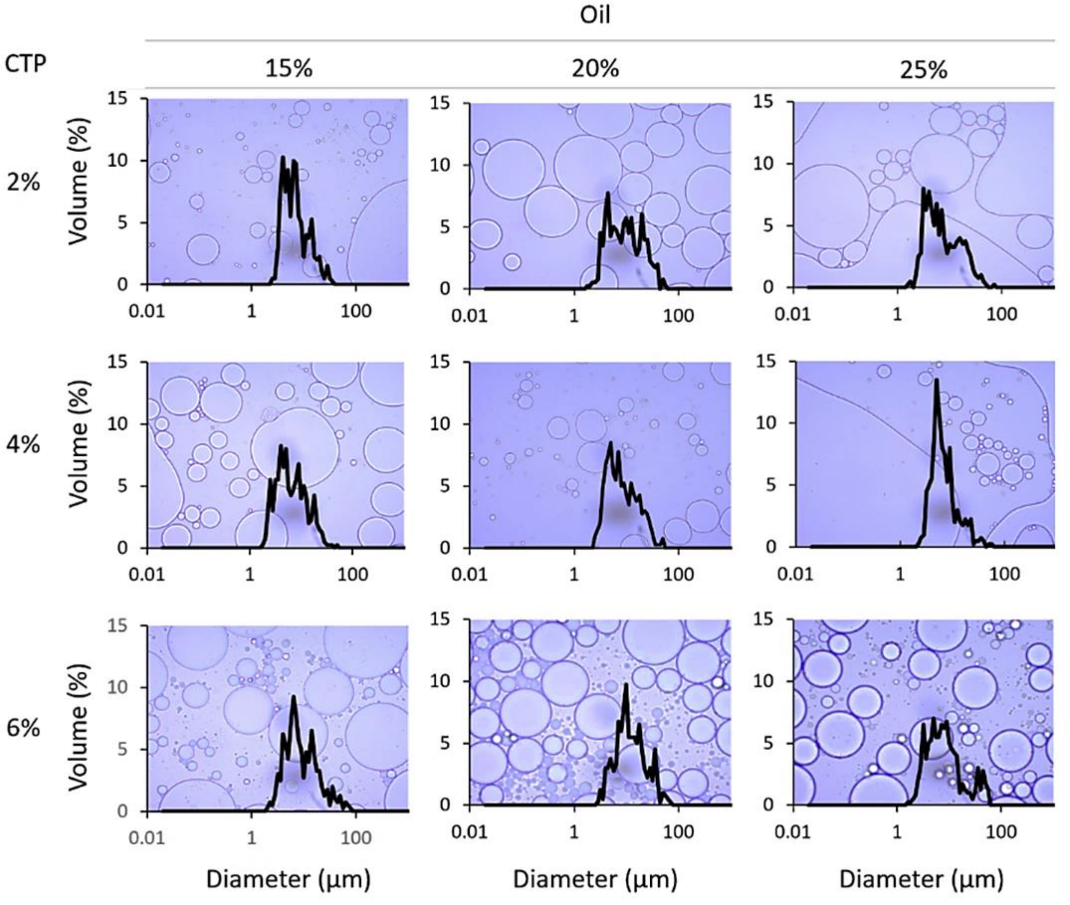

Figure 2. Micrographs and size distribution of rotor-stator (RS) emulsions. (a) 2% CTP, (b) 4% CTP, (c) 6% CTP.

3.3.2. Optical microscopy and droplet size

Table 2 shows the mean diameter of rotor-stator emulsion (RS). Emulsions prepared with 15% oil presented the smallest droplet sizes, ranging between 8.51 and 12.92 µm, followed by 25% oil, where the size fluctuated between 8.81 and 12.29 µm; the difference was not very high between them. On the other hand, the largest droplet size was observed in the emulsions prepared with 20% oil. Likewise, comparing the protein concentration, it is observed that the emulsions prepared with 4% protein have the smallest drop sizes, followed by 2% and 6%, where the different oil concentrations had larger droplets (>12 µm).

Micrographs and droplet size distribution of the emulsions are shown in Figure 2. It can be seen that all the emulsions present a multimodal distribution, agreeing with the micrograph and explaining the values and deviations presented in the droplet sizes (Table 2). In particular, in the emulsions at 25% oil with 2% and 4% protein, it was observed that the rotor-stator did not incorporate the oil and, therefore, was not emulsified. This behavior shows that 2% or 4% of CTP at high oil concentrations is insufficient to form an emulsion.

The droplet size, micrographs, and size distribution results agree with the abovementioned kinetic stability. Some works in the literature demonstrate that for an emulsion to be stable, a small droplet size is required so that gravitational forces do not affect the mobility of the droplets. Consequently, flocculation and coalescence are promoted (Vélez-Erazo et al., 2018).

In general, low CTP concentration was not enough to cover the droplet surface to stabilize the emulsions. Moreover, high CTP concentrations were not able either to form stable emulsions. In this case, high protein presence or other compounds of CTP can produce bridging flocculation or even instability for depletion flocculation (Cho & McClements, 2009).

Emulsions were subjected to ultrasound homogenization to decrease the droplet size and improve the emulsion stability; additionally, to promote steric stabilization, tara gum was added to the continuous phase.

3.4. Final emulsion (RS-US emulsion) characterization

3.4.1. Emulsion stability

Figure 3 and Table 3 show the emulsion stability results through IC, where the emulsions prepared with 2% CTP lasted 4 hours without phase separation (CI < 2%). The same happens with the 4% emulsions, which lasted the same amount of time, except for the emulsion with 15% oil (CI: 18%). Finally, emulsions with 6% CTP presented the highest CI at 4 h of storage, increasing instability with decreasing oil content (CI of 64%, 49%, and 40% for 15%, 20%, and 25% oil). These last emulsions separated after 30 minutes of storage. However, all emulsions showed phase separation after 24 hours.

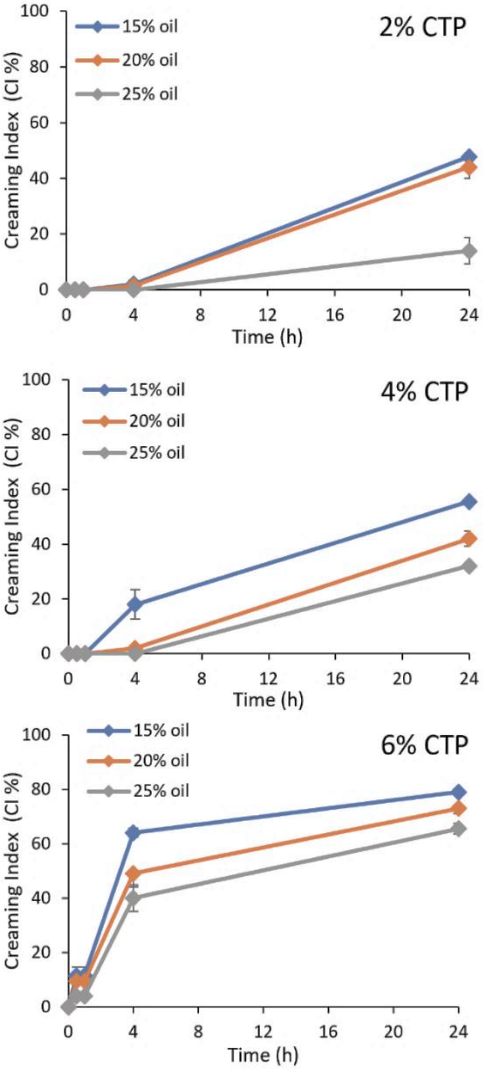

Figure 3. Creaming index of RS-US (rotor-stator + ultrasound) emulsions stabilized by commercial tara protein (CTP) at different CTP and chia oil concentrations.

3.4.2. Optical microscopy and droplet size

Table 3 shows the droplet mean diameters of the RS-US emulsions. In general, the use of ultrasound decreased the size of the droplets in all experiments, and behavior closer to the monomodal size distribution was also achieved (Figure 4), which is in agreement with micrographs and this behavior would be related to the better stability of the emulsions after using ultrasound.

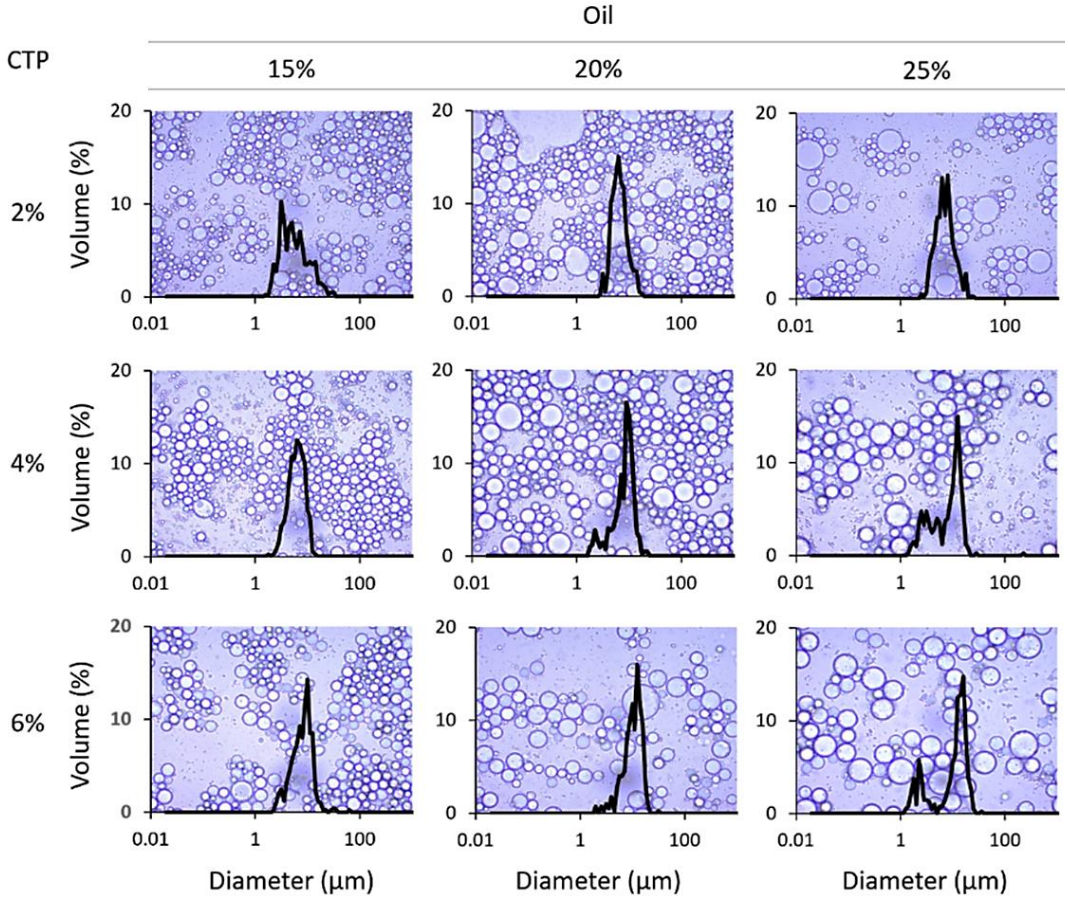

Figure 4. Micrographs and size distribution of RS-US (rotor-stator + ultrasound) emulsions. (a) 2% CTP, (b) 4% CTP, (c) 6% CTP.

The results indicated that the emulsions with 15% oil had the smallest droplets (between 6.87 and 9.16 µm). However, the size distribution of emulsion with 15% oil presented the lowest %volume, and especially, at 2% CPT, a broad size distribution (Figure 4).

Table 3
Creaming index (CI) at 4h and Mean droplet size ($D_{[th]}$) of RS-US emulsions

CTP	Oil	CI at 4h (%)	($D_{[th]}$) (µm)
2%	15%	2.03 ± 0.06 ^{Ca}	7.24 ± 5.18 ^{Bb}
	20%	1.50 ± 1.92 ^{Ba}	7.36 ± 2.68^{Cb}
	25%	0.00 ± 0.00 ^{Ba}	8.15 ± 3.64 ^{Ca}
4%	15%	18.00 ± 5.42 ^{Ba}	6.87 ± 2.30 ^{Bb}
	20%	2.00 ± 0.00 ^{Bb}	9.01 ± 3.68 ^{Ba}
	25%	0.00 ± 0.00 ^{Bb}	9.77 ± 12.62 ^{Ba}
6%	15%	64.00 ± 1.63 ^{Aa}	9.16 ± 5.01 ^{Ab}
	20%	49.00 ± 1.16 ^{Ab}	11.27 ± 4.07 ^{Aa}
	25%	40.00 ± 4.90 ^{Ac}	11.95 ± 6.43 ^{Aa}

CTP: commercial tara protein. RS-US: rotor-stator + ultrasound. Different letters indicate significant differences ($p < 0.05$). Capital letters: differentiate different percentages of protein. Lowercase letters: difference between different percentages of oil.

This same behavior was observed when comparing 2% and 4% CTP. These CTP concentrations presented the lowest droplet size (6.87 and 9.77 µm). In contrast, the emulsions with 6% presented larger and more heterogeneous droplets, with ranges from 9.16 to 11.95 µm. These findings were confirmed with microscopic images (Fig 4), which revealed, in fact, the decrease in emulsions' droplet size, the homogenization of size, and the oil incorporation because no free oil was observed in micrographs.

Alcântara et al. (2019) found values of 3.45 and 4.62 µm for emulsions prepared with chia oil and maltodextrin, whey protein isolate, and gum Arabic with the rotor-stator method, and diameters between 0.52 and 0.86 µm for rotor-stator/ ultrasound method. Likewise, in producing mono and double-layer emulsions of chia oil, the diameter found ranged between 0.93 to 1.44 µm using only ultrasound (Vélez-Erazo et al., 2018). These two investigations coincide and support the results obtained in this work by reducing the droplet size by subjecting the emulsions to the high energy capacity provided by ultrasound, which generates greater shearing of the dispersed droplets, reducing the size.

Obtaining small drop sizes was not necessarily related to the stability of the emulsions since, although the smallest drop sizes were observed at

15%, the most unstable emulsions were also obtained, especially at the lowest CTP concentration. In this case, an increase in the percentage of oil in the system (20% and 25%) could have influenced the viscosity of the emulsion and, consequently, could have decreased the mobility of the droplets (Vélez-Erazo et al., 2020).

The joint action between the decrease in size with the application of ultrasound, the steric effect with the addition of tara gum in the continuous phase, and an adequate concentration of CTP that covered the drops' surface allowed the stable systems obtention for 4 hours with very low or no phase separation. These observations are in agreement with Sun et al. (2019) and Zhou et al. (2021) who mentioned that several factors can intervene in the stability of emulsions, such as the concentration of the interfacial protein, the distribution of the droplets, the rheological properties, and the zeta potential.

Shao & Tang (2014) showed that the higher the concentration of soy protein in the emulsions, the more stable they were, substantially reducing the creaming index. On the other hand, in this work, we observed that the higher the percentage of CTP, the less stable the emulsions were, whether with the rotor-stator alone or with the rotor-stator/ ultrasound.

Likewise, tara gum contributed to RS-US emulsions having more stability. As mentioned by Vélez-Erazo et al. (2020), this polysaccharide has a high thickening capacity that reduces the mobility and coalescence of the droplets, keeping the size of the initially generated droplets stable. Also, it can be inferred that the emulsions with 6% CTP have large particles other than protein (the sample is not an isolated protein) that could not be solubilized in the CTP solution. This means there could probably be a chemical rejection with the other components, which causes a separation of the phases after 30 minutes of evaluation.

4. Conclusions

The commercial tara protein (CTP) presented a considerable protein content (45.16%), which allows it to be considered for studies of its functional properties. It was also observed that CTP had a greater oil absorption capacity than water absorption and did not present any foaming capacity. Finally, CTP has a minimum gelation concentration of 18%. Regarding the emulsifying properties, the RS-US emulsions (Rotor-stator-Ultrasound - tara gum), prepared with 25% sacha inchi oil and CTP concentrations of 2% and 4%, presented the best stability against the creaminess, remaining stable for at least 4 hours despite not having the smallest drop sizes. Future studies are necessary to deepen the use of this residue since, as shown in this work, it may have promising functional properties. By obtaining stable emulsions for at least 4 hours, this material could be used in applications that require stability for this time. Future research is also necessary to isolate the tara protein and evaluate whether it could improve the emulsions' stability in its purest form.

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Statements and Declarations

Conflict of interest

None of the authors has any conflict of interest in this research.

Author Statement

Sulca-Vásquez J. A.: conceptualization, formal analysis, investigation, visualization, Writing – original draft. Vélez-Erazo E. M.: Conceptualization, funding acquisition, methodology, project administration, resources, supervision, Writing – original draft, Writing – review & editing. Pasquel-Reátegui J. L.: project administration, Writing – review & editing, visualization. Mendieta-Taboada O. M.: supervision, Writing – review & editing.

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