Uluslararası Tarım Araştırmalarında Yenilikçi Yaklaşımlar Dergisi
International Journal of Innovative Approaches in Agricultural Research 2024, Vol. 8 (4), 391-415
https://doi.org/10.29329/ijiaar.2024.1109.10

Original article

Physical and Flowability Properties of Commercial Tomato Cream and Tarhana Soup Powders

Jasmina Tahmaz *

University of Sarajevo, Faculty of Agriculture and Food Sciences, Department of Food Technology, Sarajevo, Bosnia and Herzegovina

Abstract

This study investigated the physical properties of commercial tomato soup powders and tomato soups with tarhana noodles. Three samples of tomato cream soup without noodles and three samples of tomato soup with tarhana noodles were analysed for different physical properties (density, viscosity, granulation, bulk density, tapped density, angle of repose, adhesiveness, foaming capacity, hygroscopicity and rehydration ratio). Flowability was assessed from the values of the angle of repose, Hausner ratio, and Carr index. Thermophysical properties were estimated from moisture content. Results showed that tomato soup powders with tarhana noodles had lower viscosity, higher bulk and tapped densities, lower adhesiveness, and lower repose angle than cream soups. Considering values of the Hausner ratio and angle of repose, it can be concluded that tomato soups with tarhana noodles had better flowability and lower cohesiveness than tomato cream soups without noodles. Values of the angle of repose indicated that tarhana soup powders had moderate/fair flowability, while tomato cream soup powder had very poor flowability. Samples with higher noodle content had lower angles of repose, higher flowability, higher density, and lower dispersibility. Kinematic viscosity ranged between 15.73 and 176.80 mm2/s. Thermophysical properties increased by increasing water content.

Keywords: Tomato Cream Soup, Tarhana Soup, Powders, Physical Properties, Flowability.

Received: 30 August 2024 * **Accepted:** 14 October 2024 * **DOI:** https://doi.org/10.29329/ijiaar.2024.1109.10

---

* **Corresponding author:**

Jasmina Tahmaz, University of Sarajevo, Faculty of Agriculture and Food Sciences, Department of Food Technology, Sarajevo, Bosnia and Herzegovina.
Email: j.tahmaz@ppf.unsa.ba

INTRODUCTION

Soups are widely used liquid foods made by cooking basic and additional ingredients, usually served as warm appetizers at the beginning of a meal. Industrial soups are commonly preserved by dehydration (drying and powdering). Soups are classified as clear and cream soups. Dehydrated soups are instant products that can be reconstituted in warm water or boiled for 5 to 10 minutes. Commercial soups reached popularity after the invention of the canning process in the 19th century. The main advantages of dried soup production are its long shelf life and the possibility of being stored at room temperature (Fernandez-Lopez et al. 2020). Tomato soup is prepared from mashed tomato or tomato powder with the addition of different additional ingredients, such as spices (onion, pepper, paprika, garlic, parsley, and celery), mozzarella or other cheeses, milk powder, whey, modified corn, and noodles. It can be produced as cream or clear (thin/light soup) with or without noodles. Also, one of the popular modern trends is the industrial production of traditional dishes, such as traditional soups and tarhana. In traditional Turkish cuisine, there are many variations of tarhana soups, made from different ingredients, depending on the region. Tarhana soup is a thick, dense, or clear soup that contains tarhana noodles as the main ingredient. Traditionally, these noodles have irregular spherical shapes and are produced from fermented tarhana dough. Turkish tarhana noodles are commonly prepared by mixing yogurt, cereals, and/or legume flour with different cooked vegetables such as paprika, tomato, and onion and seasoned with spices like mint and paprika (Tarakci et al, 2004; Tahmaz et al, 2023). In Bosnia and Herzegovinian cuisine, tarhana soup came from the Ottoman Empire and has become one of the most popular dishes today. The tarhana noodles, traditional to Bosnia and Herzegovina, are prepared from a hard, dense fermented dough made from white wheat flour, eggs, and mashed tomatoes or tomato juice with or without yogurt. Sour tarhana dough is prepared after fermentation which lasts for 3-4 days at room temperature. Fermented dough is kneaded, passed through kitchen colander holes, and dried at room temperature. Bosnian tarhana soup is prepared by cooking tarhana noodles in meat broth with an addition of salt, butter, chopped/diced tomato, and spices (black paper, dried paprika powder, celery, and parsley) (Lakišić, 1999). Traditional tarhana noodles have a pleasant sour taste and aroma specific to fermented dough. In industrial conditions, tarhana soup is commonly made from ordinary non-fermented pasta dough formed in a spherical-like shape similar in size to traditional tarhana but without the fermentation. For that reason, the taste and aroma of industrial tarhana soups are not like traditional ones (Tahmaz et al, 2023). Fresh tomato fruits have the following proximate composition: moisture 94%, total solids 6%, total soluble solids 5.2%, total carbohydrates 3.41%, reduced sugars 2.96%, proteins 0.30%, fats 0.70%, and ash 0.55%. They also contain some nutritionally valuable bioactive compounds such as vitamin C 26.6 mg%, total carotenoids 37.7 mg%, lycopene 31.82 mg%, and total flavonoids 18 mg/g. Lycopene is a very strong antioxidant and red pigment in tomatoes (Ramadan et al, 2021; Ali et al, 2021). Tomatoes also contain pectin, which is the most important ingredient for the physical properties of tomato products. Over 80% of the world-produced tomatoes are consumed in the form of processed products (Gould, 1992).

MATERIAL and METHODS

Material

The research was done on 6 samples of commercial dehydrated tomato soups (Figure 1):

- TC-1 (Vispak, Visoko Bosnia and Herzegovina): tomato cream soup, ingredients: dehydrated tomatoes 30 %, wheat flour, maize starch, salt, hydrogenated vegetable fat, sugar, skimmed milk powder, dehydrated vegetables, spices., fat in powder: 6.6 %, reconstitution data: 60 g of powder in 1000 ml of water
- TC-2 (Podravka, Koprivnica, Croatia): tomato cream soup with mozzarella, ingredients: dried tomatoes (34 %), potato starch, sugar, wheat flour, salt, palm oil, corn flour, skim milk powder, mozzarella cheese powder. 2.1%, whey powder, dried celery, and onion, fat in powder 8.62 %, reconstitution: 80 g of powder in 750 ml of water
- TC-3 (Maggi Nestle Adriatic, Surčin, Serbia): tomato cream soup with basil, ingredients: corn starch, dried vegetables 26 % (tomato powder 25 %, beetroot powder, wheat flour, sugar, salt 10.3 %, spices 3.3 %, palm oil, sunflower oil, fat in powder: 4.5 %, reconstitution: 56 g of powder in 750 ml of water).
- TT-1 (Vispak, Visoko, Bosnia and Herzegovina): tarhana dehydrated soup, ingredients: noodles 55 % (wheat flour and tomato paste), concentrate 45 % (dehydrated tomato min. 25 %, potato starch, salt, hydrogenated vegetable fat, parsley, spices, flavor), fat in powder 6.66 %, reconstitution instruction: 60 g of powder in 1000 ml of water
- TT-2 (Podravka, Koprivnica, Croatia): Tarhana dehydrated soup with noodles and tomato ingredients: noodles 43%, salt, dried tomatoes 7.7 %, wheat flour, palm oil, dried beef meat extract, red pepper, fat in powder 7.14 %, reconstitution Instruction: 70 g of powder in 1000 ml of water
- TT-3 (Maggi Nestle Adriatic, Surčin, Serbia): tarhana soup, ingredients: noodles 40%, tomato powder 22 %, dried onion 1.7 %, parsley 0.3 %, other dried vegetable 2.1% (beetroot, carrot), garlic powder 0.2%, salt 11.8%, corn starch, sugar, palm oil, spices (parsley leaves, red pepper powder), fat in powder: 2.7 %, reconstitution instruction: 60 g of powder in 1000 ml of water.

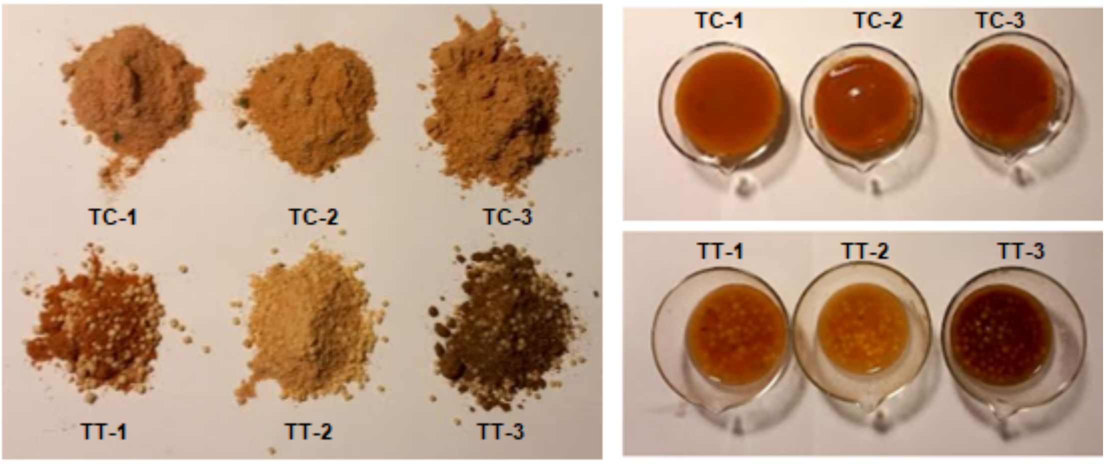

Figure 1. Image of soup powders and prepared liquid soups

*Source: the author's private archive

Methods

Chemical analysis

The moisture content of soup powders and liquid soups was determined by drying at 105 °C to constant weight (AOAC 1995). The pH value of liquid reconstituted soups was measured by a pH meter (Mettler Toledo).

Physical analysis of soup powders

The amount and size of tarhana noodles were analyzed by sieving soup powder (Prufsieb ISO 3310-1). A digital caliper measured the size of the noodle pieces. 20 measurements were done on each sample, and the mean value was calculated.

For determination of particle size distribution (granulation), the whole amount of samples in packing was sieved through sieves (Prufsieb ISO 3310-1) and 5 fractions were obtained (≥ 2.5 mm, ≥ 1 mm, ≥ 0.5 mm, ≥ 0.25 mm, and < 0.25 mm).

The determination of wettability was described by Fernandes et al (2013). 0.5 g of soup powder was put over the surface of 200 ml of distilled water (20 ◦C) without agitation, and time was recorded after all powder had been wetted.

For dispersibility determination, 5 g of powder was put in a 50 ml measuring cylinder, and distilled water (20 °C) was added to 50 ml. The mixture was vigorously stirred and left to stay for 3 h without agitation. Dispersibility [%] was calculated as a percentage of the liquid phase in total volume (50 ml) (Asma et al, 2006, Alawode et al, 2017, El-Gindy, 2018). For hygroscopicity, 1-2 g of powder was weighted into open glass containers. Samples and saturated NaCl solution were left in a desiccator for 7 days at room temperature. Hygroscopicity was calculated according to the formula (Fernandes et al, 2013):

$$Hygroscopicity\ (\%) = \frac{m_2 - m_1 - m}{m} 100$$

Where m_2 is the mass of the container with the sample after 7 days, m_1 is the mass of the empty container, and m is the initial mass of the sample (1-2 g).

For determination of rehydration ratio, 5 g of powder was mixed with 50 ml of distilled water and put to boil for 2 minutes in a covered container. After boiling, the sample was filtered through weighted medical gauze, and the gauze with the sample was dried for 4 hours at room temperature (Kour et al, 2024). The rehydration ratio was calculated according to the formula:

$$RR = \frac{\mathrm{m}_2 - \mathrm{m}_1}{m}$$

Where RR is the rehydration ratio, m_2 is the mass of the rehydrated sample on the gauze, m_1 is the mass of the gauze, and m is the initial sample mass.

The reconstitution index was calculated as the weight ratio of prepared ready-to-eat liquid soup and soup powder used for preparation. Liquid soups were prepared according to the producer's instructions.

For foam capacity determination, 2 g of the sample and 50 ml of distilled water (30 °C) are put in a 100 ml measuring cylinder. The initial volume (before shaking) of the sample with water was recorded. Then the sample was mixed with water, and the mixture was vigorously shaken for 3-5 minutes, and the foam volume was measured. The foam capacity was calculated according to the formula (Imtiaz et al, 2007):

$$Foam\ capasity\ (\%) = \frac{V_{foam}}{V_{initial}} 100$$

Bulk density was determined as the ratio of the weight and volume of powder in the measuring cylinder. Sample powders were poured gently into 50-ml graduated and tarred measuring cylinders. Bulk density was calculated as the ratio of sample weight and volume (Fernandes et al, 2013). Tapped density was determined after bulk density determination. In the same measuring cylinder, soup powders were tapped 100 times (or to a constant volume) by beating on a plain surface. The new tapped volume was recorded, and tapped density was calculated as a ratio of sample weight and tapped volume (Fernandes et al, 2013, Imtiaz et al, 2007).

Table 2 Referent values of Carr index, Hausner ratio and angle of repose for flowability estimation

Carr index	Hausner ratio	Angle of repose (degrees)	Flowability
≤10	≤1.11	≤30	Excellent, easy flow
11-15	1.12-1.18	31-35	Good
16 -20	1.19-1.25	36-40	Fair
21-25	1.26-1.34	41-45	Passable
26-31	1.35-1.45	46-55	Poor
26-31	1.35-1.45	46-55	Poor
32-37	1.46-1.59	56-65	Very poor, limited
>38	>1.60	>66	Extremely poor

Szulz and Lenart (2016), Jan et al. (2015)

Powder flowability and cohesiveness

The angle of repose, Carr index, and Hausner ratio were used as indicators of the flowability and cohesiveness of soup powders. For the determination of the angle of repose, 50 ml of dehydrated soup sample powder was carefully sloped through a funnel (D = 1 cm) on a plain surface base. The height (h) and diameter (D) of the powder heap were measured. The angle of repose (static) α was calculated as:

$$\mathrm{tg}\ \alpha = \frac{2h}{D}$$

The dynamic angle of repose was calculated as 70% of the angle of repose.

The Hausner ratio and Carr index were calculated from bulk (ρ_B) and tapped (ρ_T) densities using the following formulas (Szulz & Lenart 2016):

$$Hausner\ ratio = \frac{\rho_T}{\rho_B}$$

$$Carr\ index = \frac{(\rho_T - \rho_B)}{\rho_T} 100$$

Carr index and Hausner ratio were compared to referent values (Szulz & Lenart 2016, Jan et al, 2015; Sahni & Shere 2017), and the flowability description is given in Table 1.

Physical properties of reconstituted liquid soups

Liquid soup samples were cooked according to the producer's instructions. The density of liquid samples was calculated as a ratio of the measured weight and volume of liquid soup in a measuring cylinder. Determination of density was done at 5, 25, 55, and 100 °C.

Kinematic viscosity was measured by capillary viscometer Micro Ostwald 516 30/III at the temperature of 55 °C. Dynamic viscosity (apparent viscosity) was calculated as the product of kinematic viscosity and density at 55 °C. Apparent fluidity was calculated as a reciprocal value of dynamic viscosity (Hlavač et al, 2019; Sing & Heldman, 2003).

Determination of adhesiveness was done by the method described by Sihsobhon et al (2013) with some modifications: 100 g of prepared soup samples were placed into laboratory glass, and a wooden stick (15x1.7x0.1 cm) was immersed into the samples, taking care that 10 cm of the stick should be immersed. Adhesiveness was calculated by the formula:

$$Adhesiveness\ (\%) = \frac{m_2 - m_1}{m} 100$$

Where are: m_2 is the weight of the wooden stick with the sample, m_1 is the initial weight of the wooden stick without the sample, and m is the weight of the sample in glass.

Thermophysical properties were estimated by different mathematical models from moisture or total solids content in liquid samples.

The freezing point was calculated by Guegov`s model applicable for food with solids between 3.50 and 27% (Guegov, 1980):

$$Freezing\ point\ (°C) = 0.36 - 0.175 \cdot \%solids$$

Specific heat capacity (c_p) was calculated by the model established by Dickerson for liquid or semiliquid food (>50% of water) (Delgado et al, 2006):

$$c_p = 1674.7 + 25.12 \cdot \%water$$

Bowman`s model was used for the prediction of the thermal conductivity coefficient (Singh & Heldman, 2003).

$$\lambda = 0.056 + 0.567 \cdot \%water$$

The Thermal diffusion coefficient was calculated from the general definition equation, which assumed density, thermal conductivity, and specific heat capacity (Singh & Heldman, 2003):

$$\alpha = \frac{\lambda}{\rho \cdot c_p}$$

where α is thermal diffusion coefficient [m^2/s], λ is thermal conductivity calculated by Browman`s model [W/m K], ρ is measured density at 25C [kg/m^3], and Cp is calculated specific heat capacity [J/kg K].

Statistical analysis

Statistical analysis was performed by one-way ANOVA and Tukey test ($p \leq 0.05$) using SPSS version 20.0 (SPSS Inc., Chicago, IL, USA). All analysis was done in triplicate and results were shown as mean ± standard deviation (SD).

RESULTS and DISCUSSION

Chemical properties

The results of the chemical analysis are given in Table 2. In soup powders, moisture content ranged between 5.56 (TT-2) and 8.89% (TC-2) without significant differences between samples. Tarhana soups had slightly lower moisture content in comparison to cream soup powders, but the differences were not significant ($p \leq 0.05$). All samples had moisture content lower than 10%, which is recommended for dry food. The obtained results were in agreement with literature data for similar soup samples (Celik et al, 2010, Cagindi et al, 2016, Gandhi et al, 2017, Verma & Mogra, 2017, Goncu & Celik, 2020, Kambabazi et al, 2022, Bhargavanandha et al, 2021; Ansari et al, 2020, Tahmaz et al, 2023). Reported moisture content commonly ranged between 5.30 and 10.95% in dry tarhana soups (Celik et al, 2010, Cagindi et al, 2016, Goncu & Celik, 2020, Dagtekin & Misir, 2023, Tahmaz et al, 2023), while between 5.14 and 9.04% in tomato cream soup powders (Gandhi et al, 2017, Verma & Mogra 2017, Bhargavanandha et al, 2021). Literature data also reported that industrial tarhana soup has a lower moisture content in comparison to homemade and experimentally produced (Celik et al, 2010, Tahmaz et al, 2023). Moisture content in prepared liquid soup ranged between 87.85 and 94.52%. According to Gawad et al (2022), the moisture content in liquid cream soup was 87.5%, which is similar to sample TC-2 (tomato cream soup with mozzarella).

Table 2. Chemical properties of analyzed samples

Samples	Moisture in soup powders (%)	Moisture in liquid ready-to-eat soups (%)	pH
TC-1	6.76±0.33	94.52±0.42	4.65±0.07^{ab}
TC-2	8.89±0.54	87.85±8.41	4.90±0.14^{ab}
TC-3	6.42±0.84	93.36±0.25	4.40±0.14^{ab}
TT-1	6.42±1.86	91.06±0.27	5.20±0.28^{a}
TT-2	5.56±0.37	92.83±2.10	4.90±0.14^{ab}
TT-3	7.77±2.09	94.06±1.12	4,25±0.35^{b}

*Different small letters in columns represent statistically significant differences ($p \leq 0.05$) between samples

The pH values varied between 4.25 (TT-3) and 5.20 (TT-1) (Table 2). Tarhana soup TT-1 had significantly the highest pH value in comparison to other samples. Obtained results are in agreement with the literature data (Celik et al, 2010, Cagindi et al, 2016, Hassan & Gadallah, 2018, Ertop et al, 2019, Koc & Ozgira, 2019, Goncu & Celik, 2020, Tahmaz et al, 2023). Reported pH values ranged between 3.20 and 5.70 for tomato cream soup (Bhargavanandha et al, 2021, Gawad et al, 2022, Jamshidvand et al, 2023, Sharma et al, 2023) and between 3.6 and 6.0 for tarhana soups (Celik et al, 2010, Cagindi et al, 2016, Hassan & Gadallah, 2018, Ertop et al, 2019, Koc & Ozgira, 2019, Goncu & Celik, 2020, Gohari, 2022, Tahmaz et al, 2023) depending on the formulation.

Physical properties of soup powders

The amount of noodles in tarhana soups ranged between 43.23 and 55.32% (Table 2, Figure 2). TT-3 sample had a significantly lower content of noodles in comparison to other samples. Tahmaz et al (2023) reported 55.99% of noodles in tarhana soup from the same producer as TT-1, which is very close to the results for TT-1.

The average tarhana noodle size ranged between 1.74 and 2.46 mm (Table 3). TT-1 sample had the largest noodles, while TT-3 had the lowest. Noodles had a cylindrical shape (unlike traditional tarhana), which was obtained by cutting cylindrical extruded noodle dough (Figure 3). Traditional tarhana noodles commonly have rough, irregular, spherical/rounded shapes with different sizes. All pieces of traditional tarhana have smooth, rounded edges and sides without sharp parts. The industrial noodles found in the samples were not authentic tarhana noodles made from fermented dough. These noodles were tarhana-like noodles produced from ordinary, non-fermented dough. It can be seen (Figure 3) that the TT-1 sample had the largest noodles with a porous surface, while other samples had smooth, compact surfaces without any ruptures. TT-2 and TT-3 had smaller and more uniform noodles in comparison to TT-1.

Table 3. The proportion and size of noodles in analyzed soup samples

Samples	Amount of noodles (%)	Noodle size (mm)
TT-1	55.32±0.18^{a}	2.45±0.84^{a}
TT-2	49.77±2.05^{a}	2.01±0.51^{ab}
TT-3	43.23±1.44^{b}	1.74±0.44^{b}

*Different small letters in columns represent statistically significant differences (p≤0.05) between samples

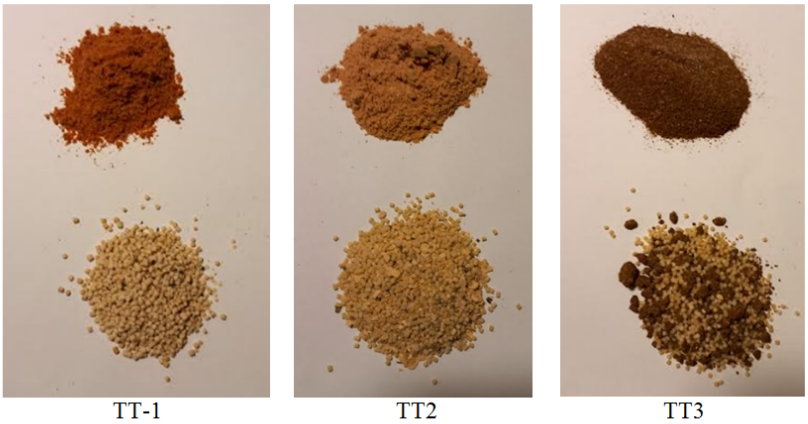

Figure 2. Image of the powder (above) and noodles (below) fractions in tarhana soup samples

*Source: the author's private archive

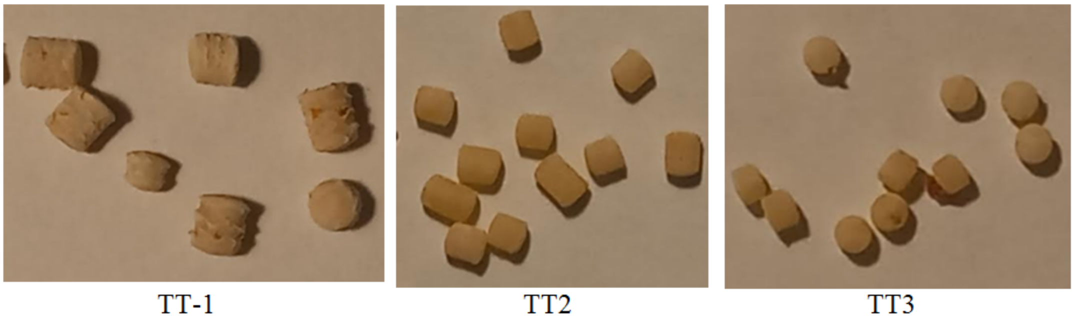

Figure 3. Shapes of noodles

*Source: the author's private archive

The results of the particle size distribution analysis are given in Table 4. It can be seen that samples differed significantly in each fraction. Cream soup samples had significantly the largest amount of very small particles (< 0.25 mm), while tarhana soups had significantly the largest amount of large particles (> 1 mm). Tomato cream soups had the highest amount of total small particles (76-91%), while tarhana soup samples had more or less similar amounts of the total large (41.98-47.12%) and the total small particles (40.81-55.35%). All samples contained the lowest amount of medium particles. Particles larger than 2.5 mm were pretty low in all samples, and noodle sizes were mostly between 1 and 2.5 mm. The large particles (>1 mm) consisted of tarhana noodles in tarhana soup samples, while the very large particle fraction (>2 mm) mostly consisted of powder lumps and small amounts of dried vegetables (Figure 2). The highest amount of powder lumps was noticed in the TT-3 sample. Considering cream soups, the highest amount of powder lumps was noticed in sample TC-2, which has the highest level of large particles (13.99%) in comparison to other cream soups (3.26-3.70%). The very large particle fraction (>2.5 mm) in all samples was the least represented fraction, which mostly contained powder lumps or some pieces of stuck or oversized noodles. Medium and small particle fractions mostly contained salt crystals and small pieces of dried vegetables and spices.

The smallest size fraction (<0.25 mm) in all samples contained only powder (a mixture of tomato powder and starch). Sample TC-1 had the highest amount of very small particles, while TT-1 had the highest amount of very large particles. The sample with the highest amount of tarhana noodles had the highest amount of very large particle fractions. When comparing tarhana soup samples, it can be seen that the sample with the lowest noodle content (TT-3) had the lowest amount of total large particles (41.98%) and a higher amount of very large particle fraction in comparison to other tarhana samples. This can be explained by observing the highest content of powder lumps in TT-3 samples (Figure 2). Because of the higher presence of powder lumps (Figures 1 and 2), TT-1 and TT-3 had higher amounts of very large particles larger than 2.5 mm. Samples with the highest amount of very large particles (>2.5 mm) were TC-2, TT-1, and TT-3. These samples also had the highest moisture content (Table 1). A substantial quantity of lumps in these samples could be explained by high moisture content. A high level of moisture probably caused the sticking of powder particles and the formation of the lumps. The medium fraction was the most dominant in TC-2 and TT-1.

In comparison to other cream soup samples, tomato soup with mozzarella (TC-2) also had the largest amount of small particles (between 0.25 and 0.5 mm), but also the smallest amount of very small particles below 0.25 mm. This could be explained by the presence of mozzarella powder, which could be assumed to have larger particles than starch and other powders. This sample had the highest sum of medium and small particles (16.62%). According to the commercial producer specification (Angelstarch, 2024), tomato cream soup should contain a minimum of 65% fine particles with a size below 0.25 mm. Results obtained for cream soups (Table 4) are in agreement with the literature (Angelstarch, 2024).

Table 4. Particle size distribution of analyzed soup powder samples (%)

Samples	**Very large ≥ 2.5 mm**	**Large ≥1 mm**	**Medium ≥ 0.50 mm**	**Small ≥ 0.25 mm**	**Very small < 0.25 mm**
TC-1	0.40±0.14^{c}	2.86±0.63^{b}	5.41±0.59^{cd}	2.71±0.9^{a}	88.63±0.29^{a}
TC-2	6.71±1.15^{a}	6.88±1.40^{b}	10.34±0.35^{ab}	6.28±3.27^{b}	69.73±0.48^{b}
TC-3	1.28±0.08^{bc}	2.42±0.39^{b}	8.23±0.66^{bc}	3.15±1-65^{b}	87.97±5.78^{a}
TT-1	9.07±1.92^{a}	38.80±4.11^{a}	11.33±1.23^{a}	17.09±3.21^{a}	23.72±4.06^{e}
TT-2	0.75±0.35^{bc}	46.37±1.16^{a}	5.81±0.30^{cd}	3.78±1.25^{b}	43.18±2.63^{d}
TT-3	5.35±1.88^{ab}	36.63±4.16^{a}	4.58±0.83^{d}	3.81±1.71^{b}	51.54±6.19^{c}
Samples	**Large ≥1 mm**		**Medium ≥ 0.50 mm**	**Small ≥ 0.25 mm**	
TC-1	3.26±0.77^{b}	5.41±0.59^{cd}	91.33±0-18^{a}	3.26±0.77^{b}	5.41±0.59^{cd}
TC-2	13.59±2.55^{b}	10.34±0.35^{ab}	76.00±2.79^{a}	13.59±2.55^{b}	10.34±0.35^{ab}
TC-3	3.70±0.47^{b}	8.23±0.66^{bc}	91.12±4.13^{a}	3.70±0.47^{b}	8.23±0.66^{bc}
TT-1	47.86±6.02^{a}	11.33±1.23^{a}	40.81±7.27^{b}	47.86±6.02^{a}	11.33±1.23^{a}
TT-2	47.12±1.51^{a}	5.81±0.30^{cd}	46.96±1.38^{b}	47.12±1.51^{a}	5.81±0.30^{cd}
TT-3	41.98±6.04^{a}	4.58±0.83^{d}	55.35±7.90^{b}	41.98±6.04^{a}	4.58±0.83^{d}

*Different small letters in columns represent statistically significant differences (p≤0.05) between samples

The results of the physical analysis performed on soup powders are given in Table 5. Bulk density ranged between 464.6 (TC-1) and 775.4 kg/m3 (TT-2). Tarhana soups had significantly (p≤0.05) higher values of bulk density in comparison to tomato cream soups. Because of the noodle's compact structure, the presence of tarhana noodles significantly (p≤0.05) increased bulk density. The sample with the lowest moisture content (TT-2) had the highest bulk density. On the other hand, samples with the lowest bulk density (TC-1 and TC-3) had the highest share of small powder particles. According to literature data, bulk density varied in ranges 450–790 kg/m3 for tomato cream soups (Verma & Mogra, 2017, Bhargavanandha et al, 2021; Kour et al, 2024), and 621–948 for tarhana soups (Koc & Ozcira, 2019; Tahmaz et al, 2023). The obtained results were in agreement with literature data, which mostly reported that tarhana soups (and other soups with noodles) had higher bulk density in comparison to tomato or other cream soups.

Table 5. Physical properties of analayzed soup powders

Samples	Bulk density (kg/m^3)	Tapped density (kg/m^3)	Hygroscopicity (%)	Wettability (s)
TC-1	464-60±19.18^{c}	748.60±1.13^{c}	25.44±8.76	39.80±7.79^{bc}
TC-2	524.30±17.39^{c}	809.78±4.60^{b}	25.59±3.08	56.63±6.33^{b}
TC-3	472.50±7.50^{c}	801.23±31.91^{bc}	21.16±6.35	6.28±2.06^{c}
TT-1	652.80±40.73^{b}	858.22±12.73^{b}	20.79±2.16	476.29±28.20^{a}
TT-2	755.40±7.92^{a}	981.21±7.99^{a}	21.25±0.66	14.52±1.30^{c}
TT-3	641.00±13.01^{b}	840.15±10.87^{b}	21.10±1-55	6.90±0.54^{c}
	Dispersibility (%)	**Foam capacity (%)**	**Rehydration ratio**	**Reconstitution index**
TC-1	65.50±3.54^{bc}	15.78±4.56^{a}	3.81±1.42	17.66
TC-2	82.50±3.54^{a}	15.71±1.27^{a}	5.52±1.53	10.37
TC-3	70.00±2.83^{abc}	14.02±0.79^{a}	4.34±1.16	14.39
TT-1	59.00±1.41^{c}	4.86±1.44^{b}	2.82±1.02	17.66
TT-2	75.00±1.41^{ab}	7.11±2.20^{ab}	2.89±0.65	15.28
TT-3	76.00±5.66^{ab}	4.83±1.34^{b}	3.07±1.19	17.66

*Different small letters in columns represent statistically significant differences ($p \leq 0.05$) between samples

Tapped density varied in the range 748.60-981.21 kg/m3. Soup samples with tarhana noodles had higher tapped density. Similar results were obtained by other authors, for example, 866-975 kg/m3 in tarhana soup powders (Koc & Ozcira, 2019, Tahmaz et al, 2023).

Hygroscopicity ranged between 20.79 and 25.44% without significant differences between samples. Tomato cream soups had slightly higher hygroscopicity than tarhana soup. Samples with the highest hygroscopicity (TC-1 and TC-2) also had the lowest values of bulk density, a low share of large particles, and a high amount of small particles. A higher amount of noodles did not have a significant influence on hygroscopicity decreasing, although the TT-1 sample had the largest noodles content and the lowest hygroscopicity in comparison to other tarhana soup samples. According to previous research (Koc & Ozcira, 2019; Elrih & Ismael, 2020), the hygroscopicity of dried soups ranged between 0.6 and 10%, depending on the sample type and determination method. Lower values obtained in previous research can be explained by some differences in determination methodology and shorter testing times. Koc and Ozcira (2019) reported that tarhana soup samples had hygroscopicity of 3.1–10%.

Dispersibility, wettability, foam capacity, rehydration ratio, and reconstitution index (Table 5) are the most relevant physical properties related to soup powder's ability to be dissolved and reconstituted. The high values of dispersibility and rehydration ratio and the low values of wettability time indicate better reconstitution properties.

Wettability time varied in a very huge range between 6.28 and 476.29 sec. The amount and the nature of the powder fraction have a crucial influence on wettability time, while noodles represent the heavy fraction, which fails very easily and fast. Because of that, samples with tarhana noodles (except

TT-1) had a shorter wettability time in comparison to cream soups. Significantly the highest wettability time was noticed in TT-1. Such a long wettability time can be related to the combination of different factors (pretty high fat content, the highest amount of medium particles with non-heavy pieces). A higher amount of low-heavy (lighter) compounds (fat and dried spices in a medium fraction) probably could cause a long wettability time. This sample hadn't only the longest wettability time; it also had the lowest dispersibility and rehydration ratio. Besides that, the two samples with the longest wettability time (TT-1 and TC-2) had the lowest fat content and potato starch in their composition, unlike other samples. TC-3 and TT-3 samples had the lowest wettability time and a high amount of small particles. The obtained results were in agreement with the previous studies. Wettability in soup powders commonly ranged between 1.16 and 585.8 s, depending on the soup type. It is not uncommon that tarhana soup powder has a long wettability time. According to Tahmaz et al (2023), the TT-1 sample also had an extremely high wettability time (585.62 s) in comparison to other samples. Koc and Ozcira (2019) also reported medium to long wettability times for tarhana soups, which varied in the range of 16.25–385.5 s. The reported wettability for different tomato cream soup powders was 48-55 s (Bhargavanandha et al, 2021) and 47.23-96.26 s (Verma & Mogra, 2017). Lower values (116–220 s) were reported for vegetable cream soups (Ocieczek & Palich, 2007, Elrih & Ismael, 2020; Bader et al, 2022).

All soup samples showed good dispersibility (59-82.50%) (Table 5). The dispersibility of tarhana soups ranged between 59 and 76%, while in tomato cream soups it ranged between 65.5 and 82.5%. Tomato cream soups had slightly higher dispersibility values than tarhana soups. Tomato soup with mozzarella (TC-2) had the highest dispersibility. Between cream soup samples, this sample had the highest amount of medium and large particles, the lowest amount of small particles, a high value of angle of repose, and a pretty low bulk density in comparison to other samples. Low bulk density probably helps the sample to disperse better. The sample with the longest wettability time, the largest volume of noodles, the lowest hygroscopicity, and the lowest dispersibility was TT-1. The obtained results were in agreement with the literature data. According to Koc and Ozgira (2019), the dispersibility of tarhana soup ranged between 31.45 and 84.56%. Tahmaz et al. (2023) reported a dispersibility of 59% in commercial tarhana soup, which was very close to the result obtained for the TT-1 sample. The other literature data reported results of dispersibility in vegetable cream soups, which ranged between 57 and 82% (Mohajan et al, 2017, SSepuuya et al, 2018, Elrih & Ismael 2020, Tahmaz et al, 2023).

Tomato cream soups had significantly higher foam capacity (Table 5) in comparison to tarhana soups. All samples had low foam capacity. The highest foam capacity was noticed in TC-1 and TC-2. TC-1 samples had the highest amount of very small fine particles (<0.25 mm), which have crucial importance in foam stabilization, while TC-2 had the highest dispersibility. The lowest amount of foam capacity was obtained in the TT-1 sample, which had the longest wettability time and the lowest dispersibility. Foam capacity had values of 4.53-15.78%. These values were in agreement with literature data (2.13–15%) reported for vegetable cream soups (Abd-Elhak & Salem 2017, Singh & Kaur, 2020, Kambabazi et al, 2022). Gohari (2022) reported an extremely high value of foam capacity for tarhana soup (43%), which could be explained by differences in tarhana soup preparation. The tarhana prepared in the mentioned research (Gohari, 2022) was traditional tarhana prepared from fermented dough, and because of that, it had higher foam capacity and more stable foam. Tarhana soup samples analyzed in this study are commercial soup samples that are prepared from ordinary, non-fermented noodles. It is well known that fermented products can form a significant amount of foam.

The rehydration ratio showed values between 2.82 and 5.52, without significant differences between samples. The highest values were noticed in samples with the highest viscosity values. Tomato cream soups had a higher rehydration ratio in comparison to tarhana soups. Tarhana soups with higher amounts of noodles had lower rehydration ratios. According to the literature, the rehydration ratio for different soups had values of 2.5–6.5 (Abdel-Haleem & Omran, 2014, Ansari et al, 2020, Bhargavanandha et al, 2021, Bader et al, 2022), which is very similar to the obtained results. Bhargavanandha et al (2021) reported that tomato cream soup had rehydration ratio values of 3.18-3.65, which is very close to the results obtained in this study (except TC-2 and TC-3). Cream soup samples TC-2 and TC-3 had slightly higher rehydration ratio values than reported by Bragavanandha et al (2021). These differences could be explained by differences in tomato soup composition, viscosity, reconstitution ratio, and moisture content. Bhargavanandha et al (2021) reported lower viscosity values for tomato cream soups (10-49.1 mPas), while the viscosity of TC2 and TC-3 samples had much higher values (131-176 mPas). Samples with lower viscosity (15.66–30.28 mPas) had a rehydration ratio more similar to those reported by Bhargavanadha et al (2021). Samples with higher viscosity commonly had a higher total solids content, and because of that, which can cause a higher rehydration ratio, while samples with a higher reconstitution index had a lower rehydration ratio.

The reconstitution index of commercial soup samples was calculated from instructions for preparation. Values ranged between 10.37 and 17.66. Higher values mean higher water content. Because of that, samples with higher moisture content in the liquid soup had a higher reconstitution ratio. Tomato cream soup with mozzarella (TC-2) had the lowest reconstitution index. This sample had the highest values for total solids, viscosity, adhesiveness, and density. The high amount of total solids increases the values of reconstitution ratio, viscosity, and density. On the other hand, higher viscosity values increase the adhesiveness and rehydration ratio. According to Ansari et al. (2020), the reconstitution ratio in the cream soup had values between 14.26 and 16.33. Jamshidvand et al (2023) reported a reconstitution ratio of 10.88 in tomato cream soups. The analyzed samples had reconstitution ratio values very similar to those reported by Ansari et al. (2020) and Jamshidvand et al (2023).

Flowability and cohesiveness of soup powders

Hausner ratio, Carr index, and angle of repose were used as indicators of the flowability and cohesiveness of soup powders (Table 6). Higher values indicate lower powder flowability. Powders with low flowability are more cohesive and more compressible. The values of the Carr index and Hausner ratio indicate pretty poor flowability properties of soup samples. There were no significant differences in the Carr index and Hausner ratio between cream soup samples and between tarhana soup samples. The lowest flowability had a TC-3 sample (tomato cream soup with mozzarella), which indicated very high cohesiveness and extremely poor flowability. This sample had a high amount of moisture content, the highest amount of small particles, a low amount of large particles, low bulk density but high tapped density, the highest angle of repose, and the lowest wettability time. This sample also contained the visible amount of powder lumps in the large particle fraction. Samples TC-2 and TC-3 contained powder lumps larger than 2.5 mm. Both indicators were higher in tomato cream soup powders than in tarhana soups. The lowest value was noticed in the TT-2 sample. This sample had the lowest moisture content, the highest tapped density, the lowest angle of repose, the highest amount of large particles between 1 and 2 mm, the lowest viscosity, and the highest fluidity, low rehydration ratio, and adhesiveness. Between tarhana soup powders, TT-2 had the highest bulk and tapped density and the smallest noodle size. All tarhana soup samples had very similar values of the Hausner ratio and Carr index. If observing only tarhana soups, the lowest flowability was in TT-1, although this sample contained the highest noodle content. Considering the values of the Hausner ratio and Carr index, the flowability of tarhana soup powders can be assessed as passable with normal (medium) cohesiveness. On the other hand, the flowability of tomato cream soups was recognized as much weaker and estimated as poor to extremely poor with high cohesiveness. Considering that the values of the Hausner ratio and Carr index amongst the tarhana soup powders were fairly close, samples with a larger concentration of noodles did not exhibit particularly intense flowability.

Values for the Hausner ratio and Carr index were in agreement with the literature data (Koc & Ozcira, 2019, Bhargavanandha et al, 2021, Kumari et al, 2023, Tahmaz et al, 2023). Reported values were in ranges 1.02-1.57 for the Hausner ratio and 23.67-34 for the Carr index. According to Tahmaz et al (2023), commercial tarhana soup powder had a lower value of Hausner ratio in comparison to cream soups (1.39 vs. 1.57). Bhargavanadha et al (2023) reported lower values (1.28–1.33) for tomato powder and tomato cream soups, probably because of different compositions, which are mostly reflected in the lower starch content in the formulation. Instead of starch, the mentioned authors used gum Arabica in different concentrations. Koc and Ozcira (2019) also obtained lower values (Hausner ratio 1.02-1.05 and Carr index 2.02-4.8) in the estimation of flowability and cohesiveness of tarhana noodles, which indicated better flowability and lower cohesiveness. Since analyzed tarhana soup samples contained powdered fractions (consisting of the mixture of starch and tomato powder) together with noodles, obtained results were expected. Because of that, the flowability of soup mixtures was lower in comparison to tarhana noodles reported by Koc and Ozcira (2019). The most similar values to the obtained results were reported by Kumari et al (2023) for cream soups and Tahmaz et al (2023) for commercial tarhana soup mixture and cream soups. According to Kumari et al (2023), cream soup powders had a Carr index of 26.36–34 and a Hausner ratio of 1.35–1.52, which indicated poor to very poor flowability. Tahmaz et al (2023) also reported that tarhana soup mixtures had higher flowability (Hausner ratio was 1.39) and lower cohesiveness in comparison to cream soups (Hausner ratio ranged from 1.56-1.57). According to those values, the flowability of tarhana soup powder was estimated as poor, while the flowability of cream soup powder was estimated as very poor.

Table 6. Assessment of flowability and cohesiveness of analyzed soup powders according to the values of Carr index, Hausner ratio, and the angle of repose

Samples	Hausner ratio	Carr index	Flowability	Cohesiveness
TC-1	1.61±0.07[a]	37.94±2.47[a]	Extremely poor	Very high, sluggish
TC-2	1.55±0.04[ab]	35.26±1.78[ab]	Very poor	Very high
TC-3	1.70±0.04[a]	41.00±1.41[a]	Extremely poor	Very high, sluggish
TT-1	1.32±0.10[bc]	23.89±5.85[bc]	Slightly fair to passable	Cohesive, normal
TT-2	1.30±0.02[c]	23.01±1.40[c]	Slightly fair to passable	Cohesive
TT-3	1.31±0.04[bc]	23.69±2.54[bc]	Slightly fair to passable	Cohesive
Samples	**Angle of repose**	**Dynamic angle of repose (degrees)**	**Flowability**	**Cohesiveness**
TC-1	39.44±2-55[abc]	27.01±1.79[abc]	Fair, aid not needed	Low, some cohesiveness
TC-2	42.09±1.47[ab]	29.40±1.03[ab]	Passable, may hang up	Low, some cohesiveness
TC-3	43.10±1.65[a]	30.17±1.16[a]	Passable, may hang up	Low, some cohesiveness
TT-1	37.08±0.14[bc]	25.90±0.10[bc]	Fair, aid not needed	Low, some cohesiveness
TT-2	36.16±0.57[c]	25.31±0.40[c]	Fair, aid not needed	Low, some cohesiveness
TT-3	39.16±1.24[abc]	27.41±0.87[abc]	Fair, aid not needed	Low some cohesiveness

*Different small letters in columns represent statistically significant differences ($p \leq 0.05$) between samples

The angle of repose ranged between 36.16 and 43.10 degrees (Table 6). Tomato cream soups had a higher angle of repose. The presence of tarhana noodles helped the powder to be loose and have a lower angle. The highest value was noticed in TC-3 and the lowest in TT-2 soup. Considering tarhana soup samples, it is obvious that samples with the lowest angle of repose had the highest noodles content, the highest amount of large particles, and the highest tapped density. On the other hand, tomato cream soup TC-3 had the highest angle of repose and the lowest bulk density and hygroscopicity. Between tarhana soup samples, the highest angle of repose was in TT-3 and the lowest was in TT-2. TT-3 had visible powder lumps in the large particle fraction (Figure), the highest moisture content, the lowest bulk density, tapped density, and hygroscopicity, the highest amount of small particles, and the lowest amount of noodles. All these characteristics caused the highest cohesiveness and the lowest flowability in comparison to other tarhana soup powders. Lower bulk density could be explained by less heavy powder particles, which easily stand on the top of the heap. Higher moisture content makes powder more sticky, which can contribute to the formation of a higher pile and increase the angle of repose. All these facts could contribute to higher cohesiveness and lower flowability. In the tarhana soup powders, the noodles are the heaviest fraction with the highest specific gravity/density. This fraction shows a higher tendency to be loose and scatter. Because of that, tarhana soup powders with higher noodle content had a lower angle of repose and better flowability. The angle of repose values indicated that the flowability of tomato cream soup powder can be assessed as fair to passable (with needed hang-up), while tarhana soup powders are fair without the need to be aided or agitated.

The obtained values are in agreement with literature data for tomato soups and similar powders. Reported values for tomato cream soup ranged between 34 and 47 degrees (Bhargavananha et al, 2021), while for vegetable cream soup from 34.17 to 57 degrees (Kamble et al, 2019; Elrih & Ismael, 2020, Yadav et al, 2022, Tahmaz et al, 2023). Tahmaz et al (2023) reported that tarhana soup had a lower angle of repose in comparison to traditional cream soups, which is in agreement with the results obtained in this study.

Physical properties of liquid soup samples

Results of the main physical properties of ready-to-eat soups are given in Table 7.

Kinematic viscosity had values of 15.73–176.80 mm^2/s, while dynamic viscosity varied between 15.66 and 176.18 mPas. Tarhana soup samples had significantly lower viscosity in comparison to cream soups. The highest viscosity was in tomato cream soup with mozzarella (TC-2). This sample had the highest content of dry matter, the highest dispersibility, adhesiveness, rehydration ratio, and the highest amount of powder used for preparation. Similar values were reported by other authors. Apparent viscosity commonly ranged between 5 and 298 mPas for similar soup samples depending on temperature and sample type. Reported values for tomato cream soups were 15-298 mPas (US FDA, 2008, Chawan et al, 2015; Verma & Mogra, 2017, Skotnicka & Osieczek, 2019; Jamshivand et al, 2023); and for tarhana soups, 5-280 mPas (Hassan & Gadallah, 2018, Ertop et al, 2019; Tahmaz et al, 2023). Values for apparent viscosity varied in ranges of 25.0-176.18 mPas (cream soups) and 15.66-30.208 mPas (tarhana soups). Tarhana soups were more unique in consistency in comparison to tomato cream soups. The consistency of tarhana soups was thin with dissolved noodles, and because of that, these samples had significantly lower viscosity in comparison to cream soups. Commercial tarhana soups had a consistency more similar to clear soups with noodles. Considering the literature data, the viscosity of commercial tarhana soup at 50 °C was 32.33 mPas (Tahmaz et al, 2023), which is very similar to the value obtained for TT-3. Lower values for other tarhana soup samples (TT-1 and TT-2) are probably obtained because of higher measuring temperatures and different methods of determination. It should be mentioned that kinematic viscosity was measured by a capillary viscometer and dynamic (apparent viscosity) was calculated from values of kinematic viscosity and density at 55°C. In other studies (Hassan & Gadallah, 2018; Ertop et al, 2019), higher viscosity values were reported for experimental tarhana soups (with fermented tarhana dough and the addition of different ingredients or processes to traditional recipes). Because of that, fermented tarhana noodles have different physical and functional properties, which consequently have an impact on final soup consistency and viscosity. Viscosity values of tomato cream soup samples varied in a higher range than commercial tarhana soups, and the obtained results were in agreement with the previous literature data. Chawan et al (2018) reported that the viscosity of commercial tomato soups at 45°C ranged between 60 and 180 mPas, while Skotniska and Ocieczek (2019) reported values of 102-298 mPas for tomato soups. The viscosity of commercial tomato soup is about 40 mPas (US FDA, 2008). According to producer specifications reported by Angelstarch (2024), viscosity values can range between 70 and 150 mPas. The obtained results are the most similar to data reported by the US FDA (2008), Chawan et al (2015), and AngelStarch (2024).

Table 7. Physical properties of reconstituted ready-to-eat soup samples

Samples	Kinematic viscosity at 55°C (mm^2/s)	Apparent viscosity at 55°C (mPas)	Apparent fluidity $(Pas)^{-1}$	Adhesiveness (%)
TC-1	25.26±4-36^{c}	25.06±4.29^{c}	40.50±6-93^{ab}	0.27±0.08^{c}
TC-2	176.80±19.52^{a}	176.18±17.78^{a}	5.71±0.57^{c}	1.31±0.01^{a}
TC-3	132.09±5.94^{b}	131.07±6.42^{b}	7.64±0.37^{c}	0.63±0.13^{b}
TT-1	17.11±4.09^{c}	16.59±3.96^{c}	62.04±14.81^{a}	0.11±0.02^{c}
TT-2	15.73±0.01^{c}	15.66±0.10^{c}	63.86±0.41^{a}	0.13±0.02^{c}
TT-3	32,03±3.82^{c}	30.28±5.40^{c}	33.56±5.98^{b}	0.09±0-00^{c}

*Different small letters in columns represent statistically significant differences ($p \leq 0.05$) between samples

Adhesiveness (Table 7) of soup samples was measured at 5 °C on liquid samples prepared according to the producer's instructions after 24 hours of cold storage. All soup samples showed expected very low adhesiveness, considering their liquid-thin consistency. Because of that, adhesiveness was measured at a temperature of 5 °C, at which the samples had the highest density and viscosity with the thickest consistency. Adhesiveness ranged between 0.11 and 1.31%. Tomato cream soups had significantly higher consistency in comparison to tarhana soups. Sample TC-2 with the highest viscosity and density had the highest adhesiveness. This sample also had the highest concentration, rehydration ratio, and reconstitution index. All these properties are closely related to each other, which also affects adhesiveness. High solid concentration and viscosity are the most relevant properties that could increase adhesiveness.

The density of soup samples varied (852.95–1340 kg/m3) in dependence on temperature and sample type (Table 8). Density decreased in all soup samples when temperature increased. The differences in density between samples were more intense at low temperatures (5 and 25 °C) than at high temperatures (55 and 100 °C). Significant differences between samples were obtained only at 5 °C. The density of all samples was the highest at 5 C and the lowest at 100 °C. The highest density values were obtained in the following samples: TT-1 at 100°C, TC-2 at 55°C, TT-2 at 25°C, and TC-2 at 5°C. Density values were the lowest in the following samples: TT-3 at 100 and 55°C, and TC-1 at 25°C and 5°C. Differences between densities at different temperatures were significant in all cream soup samples and only the TT-1 tarhana sample. The TC-2 sample had the lowest moisture content, the highest viscosity, and the highest values of density at 55 °C and 5 °C.

Table 8. Density of reconstituted ready-to-eat soups at different temperatures (kg/m^3)

Samples	100 °C	55 °C	25 °C	5 °C
TC-1	976.89±1.13^{C}	992.39±1.70^{B}	998.97±1.77^{B}	1008.83±2.68^{bA}
TC-2	957.89±37.67^{B}	997.01±9.47^{B}	1004.74±17.54^{B}	1340.00±38.18^{aA}
TC-3	951.60±26.86^{B}	992.16±4-02^{AB}	1007.23±1.74^{AB}	1050.09±36.65^{bA}
TT-1	985.33±1.43^{D}	969.65±0.21^{C}	1005.24±2.21^{B}	1012.93±1.51^{bA}
TT-2	918.61±101.40	995.85 at ±5.87	1015.50±0.71	1137.05±43.46^{ab}
TT-3	852.95±69.67	942.05±56.20	1010.74±1.32	1111.69±114.29^{b}

*Different small letters in columns represent statistically significant differences (p≤0.05) between samples, different large letters in rows represent significant differences between temperatures

According to the literature, data density varied in ranges of 963–1017 kg/m3 for tomato cream soups (US FDA 2008, Skotnicka & Ocieczek, 2019) and 996.96–1050 kg/m3 for tarhana soups (Celik et al, 2010, Tahmaz et al, 2023). Differences occurred as a result of different testing temperatures and different compositions. Only at 100 and 5 °C obtained density values (Table 8) were observed to differ from the literature. Considering that the literature data were related to the density between 20 and 55 °C, obtained results were expected.

Thermophysical properties were estimated from moisture or total solid content in reconstructed ready-to-eat soup samples (Table 9). Samples with higher moisture content had higher values of all estimated thermophysical properties, which is in agreement with literature data (Singh and Heldman 2003). Estimated thermophysical properties varied in the following ranges: specific heat capacity above freezing point 3.88-4.05 kJ/kg K, thermal conductivity coefficient 0.554-0.592 W/mK, thermal diffusion coefficient 0.142-0.146 mm^2/s, and freezing point (-1.77)-(-0.60) C. As it was expected, the highest values for all thermophysical properties were noticed in the sample with the highest moisture content (TC-1), while the lowest was in the sample with the lowest moisture content (TC-2). According to the literature, specific heat capacity for similar products has the following values: 4.02 kJ/kg K for fresh tomatoes with 93% moisture, 3.676 kJ/kg K for tomato concentrate with 81% moisture, and 4.18 kJ/kg K for water, while the thermal conductivity of fresh tomatoes was 0.528 W/mK. The reported initial freezing point of fresh tomatoes with 93% water content was -0.7 °C. Thermal conductivity, specific heat capacity, and thermal diffusion coefficient of water at 20 °C have the following values: 0.599

W/mK, 4.18 kJ/kg K, and 1.43 x 10-7 m2/s (ASHRAE, 2006; Singh & Heldman, 2003; Toledo, 1994). The estimated freezing point for soup samples with 84.85–94.52 percent moisture had very similar or slightly lower values in comparison to those reported. Lower values of freezing point are related to higher total solids. It is also important to mention that the Guegov model is suitable for the freezing point of a very huge group of liquid foods with moisture content between 73 and 96.5%. All soup samples had moisture content in the mentioned range. Lower values obtained for specific heat capacity and thermal conductivity in comparison to literature could be explained by lower moisture content in samples. The thermal diffusion coefficient also increased with higher moisture content.

Table 9. Thermophysical properties of reconstituted ready-to-eat soup samples

Samples	Specific heat capacity (kJ/kg K)	Thermal conductivity (W/m K)	Thermal diffusion (mm^2/s)	Freezing point (°C)
TC-1	4.05±0.01	0.592±0.00	0.146±0.00	-0.60±0.07
TC-2	3.88±0.21	0.554±0.05	0.142±0.00	-1.77±1.47
TC-3	4.02±0.01	0.585±0.00	0.145±0.00	-0.80±0.04
TT-1	3.96±0.01	0.572±0.00	0.144±0.00	-1.20±0.05
TT-2	4.01±0.05	0.582±0.01	0,143±0.00	-0.90±0.27
TT-3	4.04±0.01	0.589±0.01	0.144±0.00	-0.68±0.20

Conclusions

In comparison to tomato cream soup powders, tarhana soup powders had a higher share of large particles (> 1 mm), higher bulk and tapped density, lower foam capacity, hygroscopicity, angle of repose, Hausner ratio, and Carr index. Tarhana soup powders had higher flowability and lower cohesiveness in comparison to cream soups. According to the Hausner ratio and Carr index, the flowability of tarhana soup powders was assessed as fair to passable, while tomato cream soups were poor to extremely poor. Considering the angle of repose values, flowability was assessed as fair to passable (need to be hung to flow) for cream soup powders and as fair (without aid to flow) for tarhana. Samples with higher noodle content had lower dispersibility, a lower angle of repose, and better flowability. The cohesiveness of soup powders was low to normal, higher in cream soups. According to the angle of repose values, all samples had low cohesiveness. Because of that, the Hausner ratio and Carr index should be used as better flowability indicators than the angle of repose. Cream soup powders had a thicker consistency, higher rehydration ratio, a higher amount of small particles (<0.5 mm), viscosity, foam capacity, and adhesiveness, and lower bulk and tapped density powder flowability in comparison to tarhana soups. Commercial tarahana soup samples were prepared from non-fermented pasta dough, and because of that, some properties differed from the literature. The density of reconstituted samples increased when temperature decreased, while thermophysical properties increased with moisture content.

REFERENCES

Abd-Elhak, N.A., Salem, A.A. (2017). Preparation and evaluation of dried soup produced from different sweet potato varieties. *Egypt. J. Agric. Res.*, 95(3), 1161-1177.

Abdel-Haleem, A.M.H., Omran A.A. (2014). Preparation of Dried Vegetarian Soup Supplemented with Some Legumes, *Food and Nutrition Sciences*, 2014, 5, 2274-2285.

Alawode, E.K, Idowu, M.A., Adeola, A.A., Oke, E.K., Omaniyi, S.A. (2017). Some quality attributes of complementary food produced from flour blends of orange fresh potato sorghum and soybean, *Croat. J. Food Sci. Technol*., 9(2), 122-129.

Ali, M.Y., Ibn Sina, A.A., Khandker, S.S., Neesa, Tanvir, E.M., Kabir, A., Khalil, Md. I., S.H. Gen, (2021). Nutritional composition and bioactive compounds in tomatoes and their impact on human health and disease: A review. *Food Process Engineering*, *Foods,* 10, 45.

Angelstarch (2024). Instant tomato soup mix powder (https://angelstarch.com/instant-tomato-soup-mix-powder/) accessed August 2024.

Ansari F., Singh A., Baidya, K., Rana, G.K, Bharti, A. (2020). Formulation and development of instant soup mix using *Moringa oleifera* leaf powder. *Journal of Pharmacognosy and Phytochemistry*, International Web-Conference on New Trends in Agriculture, Environmental & Biological Sciences for Inclusive Development 21-22 June 2020, 429-432.

AOAC (1995). Official methods of analysis 16th Ed. Association of Official Analytical Chemists. Washington DC, USA.

ASHRAE (2006). Chapter 9, Thermal properties of food. (In Handbook: Refrigeration).

Asma, M.A., El Fadil, B., El Tinay, A. H. (2006). Development of weaning food from sorghum supplemented with legumes and oil seeds, *Food and Nutrition Bulletin*, 27(1) 26-34

Bader, S. J., El–Sayed, S. M., Galila, Asker, G.A.H. (2022). Quality Analysis of Development Dried Vegetable Soup fortified with Purslane Leaves and Seeds powder, *New Valley Journal of Agricultural Science NVJAS*. 2(6) 2022, 372-383.

Bhargavanandha, K.S., Kshirsagar, R.B., Patil, B.M., Bachate, A.H. (2021). Effect of addition of partially hydrolyzed guar gum on the quality attributes of tomato soup powder. *The Pharma Innovation Journal* 10(9), 627-634

Cagindi, O.Z. Aksoylu, N.Y. Savlak, Kose E. (2016). Comparison of physicochemical and functional properties of domestic and commercial tarhana in Turkey. *Bulg. J. Agric. Sci*., 22: 324–330.

Celik, I., Isik, F., Yilmaz Y. (2010). Chemical, rheological and sensory properties of tarhana with wheat bran as a functional ingredient. *Akademik Gida* 8(3), 11-17.

Chawan, R.A., Basu, S., Nema, P.K., Nalawade, T. (2015). Whey Based Tomato Soup Powder: Rheological and Color Properties, *International Journal of Agricultural Science and Research (IJASR)*, 5(4), 301-314.

Dağtekin, B.B., Mısır, G. B. (2023). A Preliminary Study on The Use of Protein Isolate Produced from Trout in Tarhana Soup. *Aquatic Food Studies*, 3(1), AFS182. https://doi.org/10.4194/AFS182

Delgado, A.E., Sun, D.W., Rubiolo A.C. (2006). Thermal Properties of Food. (In: Thermal Food Processing – New Technologies and Quality Issues. Ed. Sun, D.W., Francis Taylor Group.

El-Gindy, A.A. (2018). Preparation of some weaning food formulated from sweet potato, millet and quinoa, *Current Science International*, 7(4) 662-679.

Elrih, W.M., Ismael, I.A: (2020). Development of quick-dried soup powder mixes and easy to prepare. *International Journal of Multidisciplinary Research and Publications 3(3)*, 91-94.

Ertop, M.H., Cerit, Z.G., Atasoy R. (2019). Evaluation of Physicochemical, Nutritional and Sensory Properties of the Wet Tarhana, Food Science and Quality Management Vol. 83, 61-67.

Fernandes, R.V. de B., Borges, S.V., Botrel, D.A. (2013). Influence of spray drying operating conditions on microencapsulated rosemary essential oil properties. *Ciência e Tecnologia de Alimentos*, 33, 171–178.

Fernandez-Lopez, J., Bottela-Martinez, C., de Vera, C. N.R., Sayas-Barbera, M.E., Viuda-Martos, M., Sanchez-Zapata, E., Perez-Alvarez, J.A. (2020). Vegetable soups and creams: Raw materials, processing, health benefits and innovation trends, *Plants* (9), 1-33.

Gandhi, N., Singh, B., Sharma, S. (2017). Storage stability and quality assessment of instant vegetable soup mixes prepared by extrusion processing. *Bulletin on Environment, Pharmacology and Life Sciences* 6(6), 73-82.

Gawad, G.S., Shelke, R.R., Jadhao, K.V., Kahate, P.A., Nage, S.P., Bidwe, K.U. (2022). Effect of tomato powder on physico-chemical properties of paneer whey soup, *The Pharma Innovation Journal*; 11(2): 2590-2592.

Gogari, S. (2022). The Effect of Quinoa and Chickpeas Flours on the Physical, Chemical, Functional and Sensorial properties of Tarhana Soup, *Egypt Journal for Specialized Studies*,10(35), 5-28.

Goncu, A., Celik, I. (2020). Investigation of some properties of gluten-free tarhanas produced by red, green and yellow lentil whole flour, *Food Sci. Technol, Campinas*,, 40(2), 574-581.

Gould, W.A., (1992). Tomato Production, Processing & Technology – Third edition. CTI Publishing Inc.

Guegov, J., 1980. *Journal of Food Technology*, 15. 607.

Hassan, M.F.Y., Gadallah, M.G.E. (2018). Physico-chemical and Sensory Properties of Tarhana Prepared from Different Cereals and Dairy Ingredients, *Current Journal of Applied Science and Technology* 29(3): 1-14, 2018.

Hlavač, P., Božikova, M., HlavačovaZ. (2019). Selected properties of some tomato ketchup. *7th TAE 17-20 September 2019*, Prague Czech Republic, 165-170

Imtiaz, H., Burhan Uddin, M., Gulzar, M.A. (2007). Evaluation of weaning foods formulated from germinated wheat and mungbean from Bangladesh. *African Journal of Food Science*, 5 (17), 897-903

Jamshidvand, M., Gallan, N., Dermiki, M. (2023). Development of High Protein Tomato Soup Using Milk Protein Concentrate and Pea Protein Isolate, *Chemical Engineering Transactions*, 102, 43-48.

Jan, S., Rafiq, S.I., Saxena, D.C (2015). Effect of Physical Properties on Flow Ability of Commercial Rice Flour/Powder for Effective Bulk Handling. *International Journal of Computer Applications, 11* (0975 – 8887),

Kambabazi, M-R., Okoth, M.W., Ngala, S., Njue, L., Vasanthakaalam, H. (2022). Physicochemical properties and sensory evaluation of a bean-based composite soup flour, *Legume Science,* 4 (15), 1-10.

Kamble, K.S., Mote, G.V., Sahoo, A.K. (2019). Process development for instant Moringa pod soup powder supplemented with herbs. *Journal of Pharmacognosy and Phytochemistry*, 8(3), 3281-3286.

Koc, G. C., Ozcira, N. (2019). Chemical composition, functional, powder, and sensory properties of tarhana enriched with wheat germ, *J. Food Sci Technol*., 56 (12), 5204–5213.

Kour, K., Sood, M., Bandral, J.D., Gupta, N., Kumari, A. (2024). Physical, Functional and Microbiological Parameters of Tomato-Broccoli Blended Instant Vegetable Soup Mix, *European Journal of Nutrition & Food Safety*, 16(4), 102-109.

Kumari, A., Kaushik, N., Slizyte, R., Khusboo (2023). Formulation of a Ready-to-Cook Soup Mix Using Microencapsulated Protein Hydrolysate Obtained from Pink Perch By-Product, *Polish Journal of Food and Nutrition Sciences*, 73(3), 253–264.

Lakišić, A. (1999). Bosanski kuhar – Tradicionalno kulinarstvo u Bosni i Hercegovini, 6. Izd. Svjetlost Sarajevo (In Bosnian).

Mohajan, S., Orchy, T.N., Farzana, T. (2018). Effect of incorporation of soy flour on functional, nutritional and sensory properties of mushroom-moringa-supplemented healthy soup. *Food Science & Nutrition,* 6(3), 549–556.

Ocieczek, A., Palich P. (2007). The influence of development of the specific surface of sorption on the wettability of instant soups. Czes. J. Food Sci. 25(6), 333-338.

Ramadan, M.A., Khalil, K. I., El Robi, M.H., Othman, A.S. (2021). Quality characteristics of Tomato Fruits for processing based on chemical composition and functional compounds in response to fertilization rate with potassium humate. *Fayoum Journal of Agricultural Research and Development* FJARD, 35 (2): 245-258.

Sahni, S., Shere, D.M. (2017). Comparative evaluation of physico-chemical and functional properties of apple, carrot and beetroot pomace powders, *Int J. Food Ferment Technol*., 7(2), 317-323.

Sihsobhon, C., Chompreeda, P., Haruthaithanasan, V, Suwonsichon, T. (2013). Physicochemical Properties and Sensory Evaluation of the Formulated Reduced Calorie Satay Sauce, *Kmitil Science and Technology Journal,* 13 (2), 96-102

Singh, P.R., Heldman, D.R. (2003). Introduction to food process engineering, 3rd Edition. Academic Press. Food science and technology, International series.

Singh, V., Kaur, K. (2020). Development, formulation and shelf life evaluation of baby corn soup mix from industrial by-products, *Journal of Food Science and Technology*, 57, 1917–1925.

Skotnicka, M., Ocieczek, A. (2019). Influence of tomato cream soup physical parameters on satiety potential level. *Acta Agroph*. 26(4), 5-21

SSepuuya, G., Katongole, J., Tumuhimbise, G.A. (2018). Contribution of instant amaranth (*Amaranthus hypochondriacus L.*) - based vegetable soup to nourishment of boarding school adolescent. *Food Science & Nutrition* Wiley Periodicals Inc., 6(6), 1402-1409.

Szulz, K., Lenart, A. (2016). Effect of composition on physical properties of food powders, *International Agrophysics* 30, 237-243 doi. 10.1515/intag-2015-0084.

Tahmaz, J., Somun, I., Operta, S., Oras, A., Alkić-Subašić, M., Karahmet, E. (2023). Quality of Commercial Blends for Tarhana, Bey's and Sarajevska Soup, M. Brka et al. (Eds.): *Agriconference 2022*, LNBE, Springer Nature Switzerland AG 2023, 285–302.

Tarakci, Z., Dogan, I.S., Koca A.F. (2004). A traditional fermented Turkish soup, tarhana, formulated with corn flour and whey. *Int. J. Food Science and Technology* 39, 455 – 458

Toledo, R. T. (1999). Fundamentals of Food Process Engineering, 4th ed., AP Elsevier.

US FDA/CFSAN (2008). Acidified and low acid canned foods – Approximate pH of foods and food products. 1-13.

Verma, A., Mogra, R. (2017). Process for the preparation of value added tomato-mushroom soup mix incorporated with *Psillium husk* and its quality evaluation. *International Journal of Pure & Applied Bioscience,* 5(5), 1502-1507.

Yadav, Y.S., Prasad, K., Kumar, S. (2022). Ingredients interactions effect on development and characterization of rice flour and *Moringa oleifera* leaf powder based instant soup mix. *Chemical Science Review and Letters,* 11 (42), 111-122.