Very Rice Results: Particle Size Analysis of Rice Derivatives

Relevant for: PSA, laser diffraction, food industry, starch, plant-based milk, plant protein

The particle size distributions (PSD) of rice milk, rice flour and rice proteins were characterized with the PSA in liquid and dry mode. The PSD of rice milk displays a major peak at 6 µm likely representing starch granules, while that of rice proteins shows a major peak around 50 µm likely corresponding to protein aggregates. Rice flour showed a bimodal profile indicating the presence of both starch and proteins.

1 Introduction

Rice (*Oryza sativa*) is a staple food for more than half of humanity, and is not only and a major source of nutritional carbohydrates but also of proteins.

Starch is the major component of rice, accounting for over 80 % of constituents. Rice starch is organized in polyhedral, irregular granules whose particle size varies between 2 and 7 µm, making them the smallest starch granules from all cereals [1].

Protein content of rice grains accounts for under 10 % of the mass, but proteins extracted from the seed, and even more from rice bran, have a superior nutritional quality compared to other cereal-derived proteins. Their amino acid score - a measure of the balance between the different amino acids in relation to human nutritional needs - can reach 95 % and is thus comparable to the score of soy and dairy products, which is close to 100 % [2]. The major rice proteins (albumin, glutelin, globulin, and prolamin) are also unrelated to gluten, making *Oryza sativa* a hypoallergenic alternative to other cereals [3].

Because of these health advantages and the widespread availability of the basis product, rice derivatives such as rice milk, flour, and extracted proteins are increasingly used in the fast-growing market of gluten-free and plant-based food alternatives. Manufacturing processes often involve several milling steps followed by complex physical and/or chemical extraction steps. This leads to a potentially high variability of the resulting product, highlighting the need for a strict quality control process along the manufacturing chain.

Here we show how Anton Paar's PSA, which determines the particle size distribution of either dry powders or liquid suspensions by laser diffraction, can be used in this context.

2 Experimental Setup

2.1 Samples

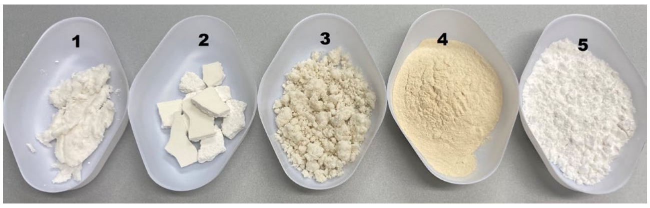

Figure 1: Visual aspect of (1) wet rice milk, (2) dry rice milk, (3) wet rice protein, (4) dry rice protein, and (5) rice flour.

Two types of rice milk were analyzed: a paste-like, hydrated sample hereafter referred to as wet rice milk (see Figure 1-1), and a dehydrated sample consisting of large agglomerates, referred to as dry rice milk (Figure 1-2).

Rice protein was also analyzed in hydrated form (wet rice protein, Figure 1-3) and in a dry, finely powdered form (dry rice protein, Figure 1-4).

A sample of rice flour in dry, finely powdered form was also analyzed (Figure 1-5).

Samples 1, 2 and 3 (rice milk & wet rice protein) were analyzed in liquid mode, as their hydrated or agglomerated state did not enable a dry measurement. Samples 4 & 5 (dry rice protein, rice flour) were analyzed in dry mode.

2.2 Liquid Measurements

Water was used as solvent for liquid measurements. The wet rice milk paste dissolved quickly in the sample tank and did not require ultrasonication. In contrast, dry rice milk had to be pre-dispersed in a water-filled beaker and the agglomerates broken down manually to ensure proper dispersion in the PSA. Additionally, a 2-minute ultrasonication step was performed directly in the PSA's sample tank before the measurement.

The wet protein sample also required both a manual pre-dispersion step and ultrasonication. By performing a measurement series using ultrasonication in increments of 1 minute, we determined that the wet protein dispersion reaches a stable state after 12 minutes of ultrasonication (data not shown).

The Mie reconstruction mode was use for data analysis. The refractive index of rice milk was approximated to that of starch (1.53 - i0.01), while that of rice proteins was set to 1.52 - i0.01 [4]. Input parameters are detailed in Table 1.

Parameter	Wet rice milk	Dry rice milk	Wet protein
Pre-dispersion in water-filled beaker	None	5 minutes, breaking of aggregates with spatula	5 minutes, breaking of aggregates with spatula
Pre-dispersion in tank	2 min	2 min	12 minutes
Ultrasound during pre-dispersion	**No**	**50 W**	**50 W**
Ultrasound during measurement	No	No	No
Stirrer speed	Fast (350 rpm)	Fast (350 rpm)	Fast (350 rpm)
Pump speed	Fast (300 rpm)	Fast (300 rpm)	Fast (300 rpm)
Reconstruction mode	Mie	Mie	Mie
Refractive index of sample	1.53 – i 0.01 [Starch]	1.53 – i 0.01 [Starch]	1.52 – i 0.01 [Rice proteins]
Analysis mode	General	General	General
Dispersant	Water	Water	Water
Target obscuration	12 - 25 %	12 - 25 %	12 – 25 %
Measurement time	1 min	1 min	1 min

Table 1: Measurement parameters for the liquid mode measurement of wet & dry rice milk, and of wet rice protein.

2.3 Dry Measurements

Dry rice protein and rice flour were measured in dry mode using the Venturi dispersion, at a pressure of 2000 mbar. The input parameters are detailed in Table 2.

Parameter	Dry rice protein	Rice flour
Vibrator duty cycle	50 %	50 %
Vibrator frequency	46 Hz	50 Hz
Air pressure	2000 mbar	2000 mbar
Reconstruction mode	Mie	Mie
Analysis mode	General	General
Target obscuration	1 - 5 %	1 - 5 %
Refractive index	1.52 – i0.01 [Rice proteins]	1.53 – i0.01 [Starch]
Measurement time	10 sec	10 sec

Table 2: Measurement parameters for the dry mode measurement of dry rice protein and rice flour.

3 Results and Discussion

3.1 Rice Milk Measurements

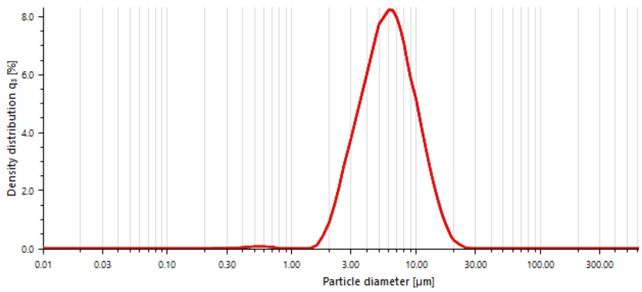

Figure 2: Volume-weighted particle size distribution of wet rice milk, measured in liquid mode. Overlay of 5 consecutive measurements.

	D_{10} [µm]	D_{50} [µm]	D_{90} [µm]	D[4,3] [µm]	Span
Mean	2.85	5.53	10.74	6.65	1.43
Std. Dev.	0.001	0.003	0.018	0.006	0.003
RSD	0.04 %	0.05 %	0.16 %	0.09 %	0.19 %

Table 3: Particle size distribution of wet rice milk: statistics table for 5 consecutive measurements.

As shown in Figure 2 and Table 3 above, the particle size distribution of wet rice milk measured in liquid mode displays a mostly monomodal profile, with a major peak around 6 µm. This likely corresponds to starch granules, the size of which is described in the literature as being between 2 and 7 µm in diameter [1]. Results show an excellent repeatability, with relative standard deviations (RSD) for the main D-values, the mean size (D[4,3]) and the span (broadness of the distribution) all well below 0.2 %.

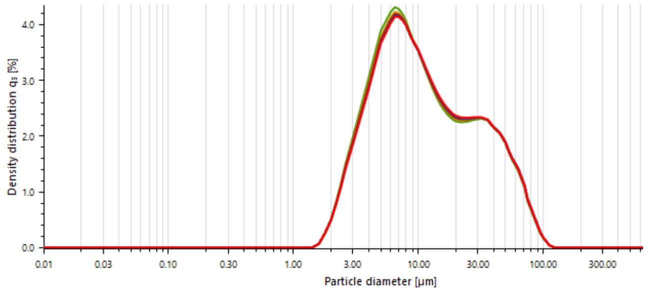

Figure 3: Volume-weighted particle size distribution of dry rice milk, measured in liquid mode. Overlay of 5 consecutive measurements.

	D_{10} [µm]	D_{50} [µm]	D_{90} [µm]	D[4,3] [µm]	Span
Mean	3.34	9.33	42.9	17.78	4.24
Std. Dev.	0.021	0.177	0.334	0.185	0.052
RSD	0.63 %	1.90 %	0.78 %	1.04 %	1.22 %

Table 4: Particle size distribution of dry rice milk: statistics table for 5 consecutive measurements.

Dry rice milk proved more difficult to disperse in water than wet rice milk. Yet after a manual pre-dispersion step and an ultrasonication step, results from the measurement series also display good repeatability (see Figure 3 and Table 4). However, while the particle size distribution also displays a major peak around 6 µm (starch granules), it also shows an additional peak around 30-40 µm. As a consequence, the mean particle size of dry rice milk (17 µm) is significantly higher than that of wet rice milk (6.6 µm). This suggests that while wet rice milk is predominantly composed of well dispersed starch granules, the dry rice milk additionally contained either hardly dispersible starch aggregates or a second component, e.g., a protein fraction.

3.2 Rice Protein Measurements

The wet rice protein was measured in liquid mode and proved difficult to disperse, needing a manual pre-dispersion step and a 12-minute continuous ultrasonication step. Yet, as shown in Figure 4 and Table 5, results show excellent repeatability, indicating a stable dispersion.

The particle size distribution shows a largely monomodal peak with a mode around 50-60 µm. This is consistent with the particle size of rice protein aggregates reported in the literature (30 – 90 µm) [5] [6]. However, the shoulder in the particle size distribution around 3-5 µm suggests that a minor fraction of starch granules is present. A second shoulder in the particle size distribution around 300 µm also suggests that some larger protein aggregates are present. In all, the PSD displays a span of over 2.8, indicative of a broad distribution.

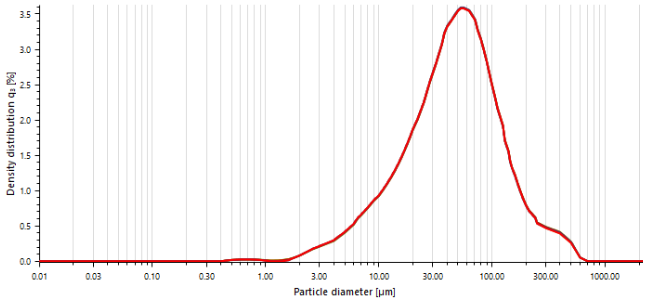

Figure 4: Volume-weighted particle size distribution of wet rice protein, measured in liquid mode. Overlay of 5 consecutive measurements.

	D_{10} [µm]	D_{50} [µm]	D_{90} [µm]	D[4,3] [µm]	Span
Mean	10.33	45.44	139.3	70.09	2.84
Std. Dev.	0.037	0.104	0.738	0.319	0.012
RSD	0.36 %	0.23 %	0.53 %	0.46 %	0.41 %

Table 5: Particle size distribution of wet rice protein: statistics table for 5 consecutive measurements.

The dry protein sample was measured in dry mode and results are presented in Figure 5 and Table 6.

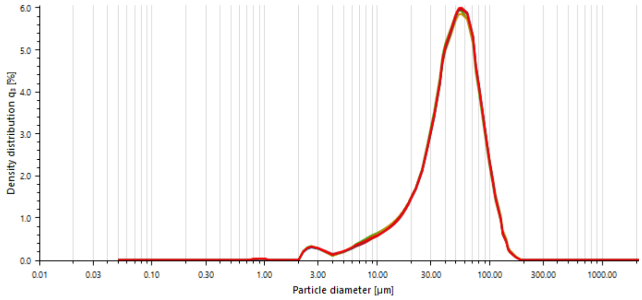

Figure 5: Volume-weighted particle size distribution of dry rice protein, measured in dry mode. Overlay of 5 consecutive measurements.

	D_{10} [µm]	D_{50} [µm]	D_{90} [µm]	D[4,3] [µm]	Span
Mean	15.09	45.57	85.35	50.88	1.54
Std. Dev.	0.300	0.385	0.734	0.393	0.016
RSD	1.99 %	0.85 %	0.86 %	0.77 %	1.06 %

Table 6: Particle size distribution of dry rice protein: statistics table for 5 consecutive measurements.

The PSD also shows a largely monomodal profile peaking around 50-60 µm, corresponding to the size of putative protein aggregates. A shoulder around 3 µm suggests that this preparation also contains a minor fraction of starch granules. Interestingly, the large aggregates (> 300 µm) observed in the wet protein preparations are absent from the dry protein sample. Hence the span for the dry protein measurement (1.54) was significantly smaller than for the wet protein measurements.

Measurement repeatability proved excellent for dry measurement standards (RSD < 2 %).

3.3 Rice Flour Measurements

Rice flour results are presented in Figure 6 and Table 7 below. The PSD shows a clearly bimodal profile, with two peaks of roughly identical intensity at respectively 6 µm and 60 µm.

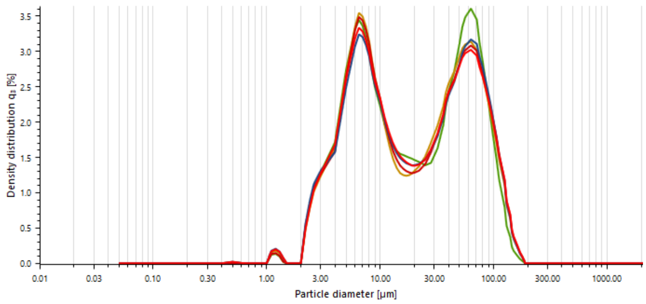

Figure 6: Volume-weighted particle size distribution of rice flour, measured in dry mode. Overlay of 5 consecutive measurements.

	D_{10} [µm]	D_{50} [µm]	D_{90} [µm]	D[4,3] [µm]	Span
Mean	3.95	16.94	81.30	33.71	4.57
Std. Dev.	0.043	0.409	2.307	0.579	0.148
RSD	1.09 %	2.42 %	2.84 %	1.72 %	3.23 %

Table 7: Particle size distribution of rice flour: statistics table for 5 consecutive measurements.

Given the results obtained for rice milk and rice protein extracts, this suggests that both starch granules (at ca. 6 µm) and rice protein aggregates (at ca. 60 µm) can be identified in rice flour measured in dry mode.

Of note, one should keep in mind that PSDs obtained by laser diffraction are volume-based, and thus give greater weighting to large particles. This explains why the peak corresponding to the protein aggregates appears as prominent as that of the putative starch granules, even though the expected protein content of milled rice should not exceed 10 % per weight.

4 Conclusion

The PSA appears ideally suited to determine the particle size distribution of rice derivatives by laser diffraction. The PSDs of the different products display two prominent peaks, one at 6 µm which likely corresponds to rice starch granules, and another at 50-60 µm, likely representing protein aggregates.

Both liquid and dry measurements identified these fractions with excellent repeatability.

5 References

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