QUINOA AS A SUBSTITUTE FOR SEMOLINA: SOME ASPECTS AND PROBLEMS OF INTRODUCTION

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Abstract: *Semolina is one of the most widely used kinds of finely ground cereals, which is easy to digest and assimilate. However, it consists of significant amount of heavy gluten which is not suited for people suffering from celiac diseases. Besides, the content of proteins, vitamins and microelements in semolina is comparatively poor.*
Quinoa is a pseudo-grain crop imported mostly from South America. Quinoa can be considered as a substitute for semolina since it is rich in vitamins, proteins, amino acids and microelements, and targeted especially to the customers suffering from celiac disease, allergic to gluten or having special dietary requirements.
It is important to investigate and compare some rheological properties of quinoa and semolina in order to ensure safe and effective interchanges in the technology of cereals production.
It has been found that swelling of the quinoa mixtures is higher than that of the semolina mixtures. A rise in temperature causes initial increase in volume of the dispersed phase particles followed by fast destruction of the cereal disperse systems. Viscosity of the quinoa mixtures shows a sharp rise when mass percent of the cereal exceeds 13 % while in case of semolina mixtures, the same phenomenon occurs after 16 %. A rise in viscosity is unwanted since it lowers the quality of the material used. It can be avoided to some extent by partial substitution of semolina with quinoa as 1:0.8.

Keywords: *quinoa; semolina; mixtures viscosity; viscosimetry.*

1. Introduction

Semolina is a widely used kind of finely ground wheat cereals, which is popular due to its easy digestion and assimilation, low price and availability for any group of consumers. On the other hand, the proteins, vitamins and microelements contents in semolina are comparatively low [1]. Moreover, it is not recommended for people under 2 and over 45 because of phytin, which causes decalcification and loss of magnesium. Besides, its mixture with milk is highly caloric and may cause obesity or gaining extra weight. Quinoa is a wheat-type pseudo-grain culture imported from South America. It is very valuable cereal with high content of vitamins, microelements, amino acids and proteins. The year 2013 was proclaimed in UNO as "quinoa year" [2-5]. It is even called as "vegetable breast milk". It is especially important because there is no gluten in quinoa [6-8]. Nutritive values of both cereals are close (360 and 368 kcal/100 g) while the protein content in quinoa is somewhat higher as compared to that in semolina (14-23 g/100g vs 12.7 g/100 g respectively) [1, 6].

Many food processing operations involve mechanical manipulation with materials

(mixing, plasticizing and others). In this context, a nature of the cereal, its mechanical characteristics are the key factors governing quality of various confectionary items and half-finished products. For instance, pudding production requires only extra or first quality grade cereal like semolina. Other substitutes can only be used in case they do not depreciate the final product's consumer qualities. Substitution raw materials can ensure some decrease in the product price and/or widen a circle of potential consumers by lifting some dietary restrictions.

Complete or partial substitution of the wheat flour is one of many ways to reach the above aims. However, some physico-chemical parameters of the wheat and quinoa flours are significantly different (first of all, water absorbing capacities), fact which puts serious obstacles on the possibility of direct substitution of semolina with quinoa.

Different water absorbing capacities cause changes in the flour particles swelling, influence the distance between the particles, inter-particle gap width and, as a result, cause changes in the system's internal friction (viscosity) value.

Therefore, a comparative analysis of water absorbing capacity values should be carried out for semolina and quinoa cereals in order to evaluate and elaborate changes in the corresponding food processing flowcharts.

Our paper addresses this problem as well as it investigates the influence of cereals' concentration on the rheological conditions of their water suspensions.

2. Experimental

All investigations were carried out with different aqueous suspensions of quinoa and semolina. Source cereals characteristics were the following.

Table 1.
Granulometric distribution of the source semolina particles

Size, μm	Content (%)
0 – 50	15,5
50 – 100	65,5
100 – 250	15,0

Semolina grains: water content – 15 %, packing density 1.1 cm^3/g, granulometric particles distribution – see Table 1.

Quinoa cereals: water content 6.5 %, packing density 0.9 cm^3/g, granulometric particles distribution – see Table 2.

Table 2.
Granulometric distribution of the source quinoa particles

Particle size, μm	Content (%)
0 – 50	27.5
50 – 100	58.0
100 – 250	14.5

Sedimentation cylinders were used to determine water absorbing capacity of the samples following the procedure: a sample was placed in a beaker and then 5-6 ml of water was added. The mixture was stirred with a glass stick until a uniform viscous mass was formed. If needed, 2-3 ml of water were added and then the mixtures were placed in the sedimentation cylinders, filled with water to the upper mark and left under fixed temperature. The sedimentation values were recorded in 0.5, 1, 2 and 12 hours. All these experiments were carried out at initial temperature 20, 50 and 70 ^{0}C. All systems were heated up to the corresponding temperatures and then they were naturally cooled down to room temperature. Shearing stress value and viscosity were measured using the rotational viscosimeter Rheotest-2, S and S_3 cylinders sets and the following calculation formulas (1), (2) were used:

$$\tau_r = z \times a, \tag{1}$$

where z – cylinder constant, din/cm^2; a – reading of the shearing scale, τ_r – shearing stress value;

$$\eta = \tau_r \div D_r \times 100, \qquad (2)$$

where η – effective viscosity, Pa·s, τ_r – shearing stress value, din/cm^2, D_r – shearing rate, s^{-1}.

3. Results and discussion

As seen from the experimental data, the swelling degree of semolina (Fig. 1) and quinoa (Fig. 2) are significantly different. The swelling degree of quinoa is higher

than that of semolina and this fact should be accounted by the substitution of the latter with the former. This difference is caused by the higher content of the smaller particles in quinoa cereals and lower water content in this grain. On the other hand, quinoa can be easily hydrolyzed causing the formation of white jellylike hydrolysis products shell on each grain.
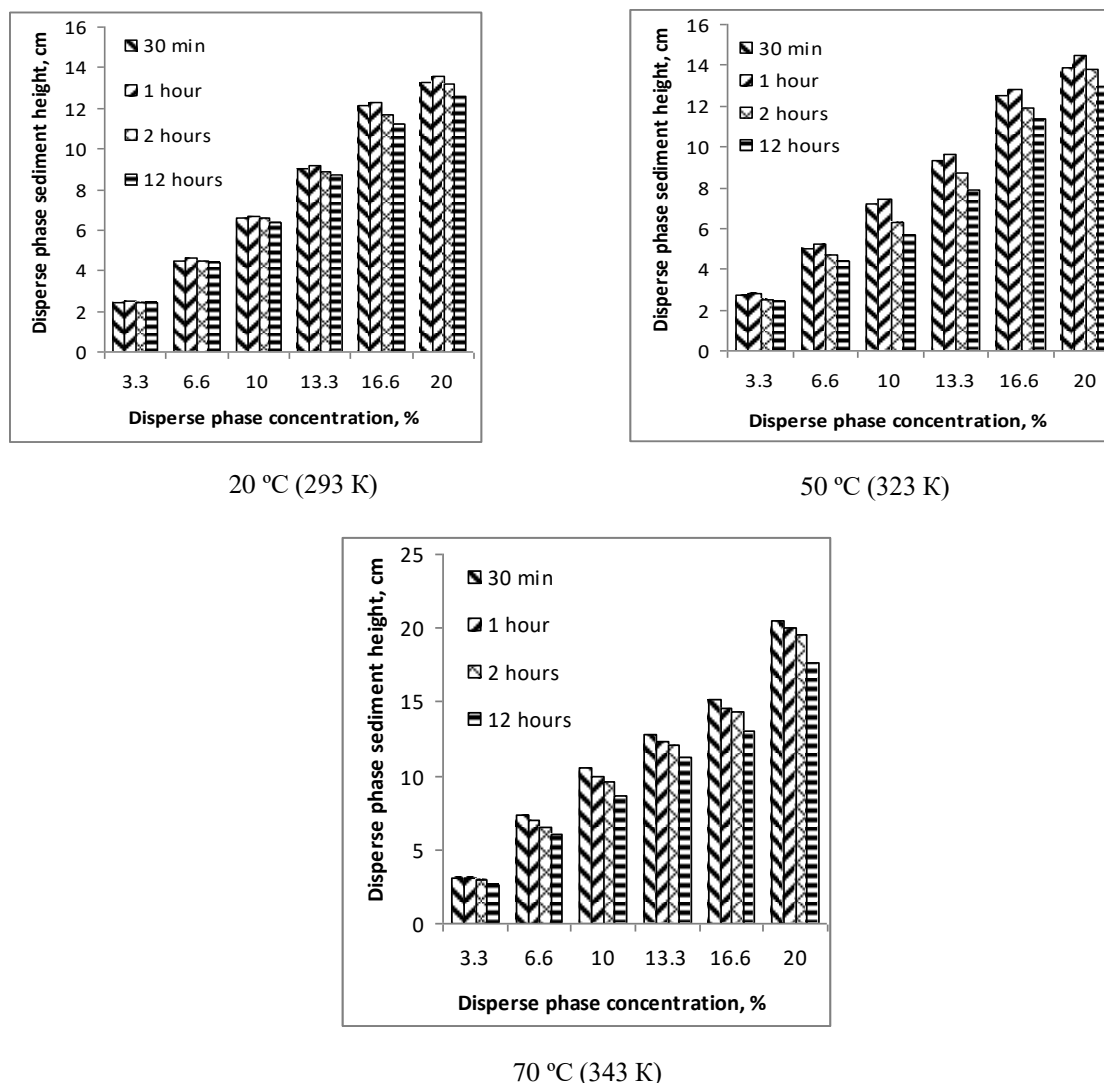

20 ºC (293 K)

50 ºC (323 K)

70 ºC (343 K)

Fig. 1. Swelling degree for semolina samples

As seen from Fig. 1, the maximum disperse phase sediment height is reached at 20 ^{0}C in 1 hour followed by gradual compacting of the sediment. In the beginning, the compacting runs slowly, then its rate accelerates. It can be seen visually that the

sediment becomes non-uniform, the particles agglutinate and thin layers of the liquid appear in its bulk. The same tendencies were registered for the systems at 50 ^{0}C. When the temperature was of 70 ^{0}C, the maximum sediment height was reached

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even in 30 min and then it compacted at comparatively high rate. Some rise in the initial sediment volume with temperature is also evident. We believe that this effect is caused by faster formation of the particle shells at higher temperature.

However, higher temperatures push up the rate of various microbes' proliferation, which manifests itself through intense gas release conjugated with raise in the solution turbidity after 24 hours at the initial temperature 20 ^{0}C and after 12 hours – at 50 and 70 ^{0}C.

20 ºC (293 K)

50 ºC (323 K)

70 ºC (343 K)
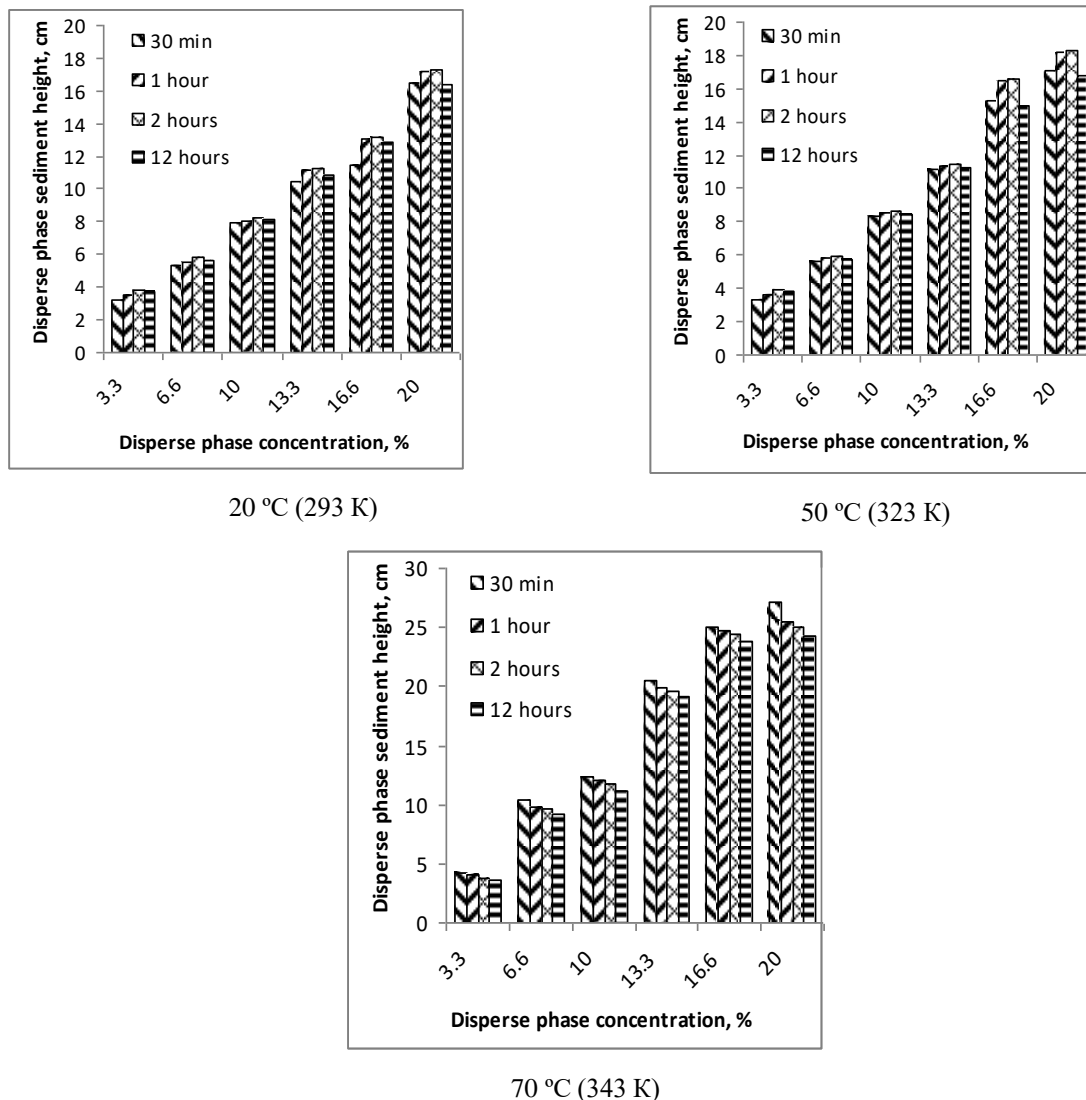
Fig. 2. Swelling degree for quinoa samples

The temperature swelling coefficient was calculated as a ratio between the system's volume at the temperature T+10 divided by the ratio at the temperature T. These values for semolina were ~1.05 at the temperatures 20-50 ^{0}C and ~1.07 for the range 50-70 ^{0}C. The same coefficients for the quinoa mixtures were 1.06 and 1.1 corresponding-

ly, which is quite close to the semolina values. All these values are subject to change with time because of decomposition of the structures formed initially in the mixtures. That is why all the coefficients were determined after 30 min of keeping of the mixtures. It is unlikely that any mix-

tures would be stored longer during real manufacturing.

The concentration changes in viscosity of semolina and quinoa water suspensions are shown in the Fig. 3. It can be seen that both values rise with concentration, which is a proof of dependence of the system's viscosity on volumetric concentration of the disperse phase.
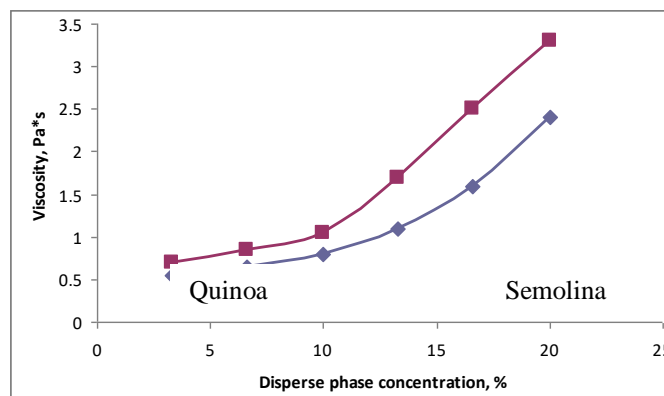
Fig 3. Dependence of the semolina and quinoa water suspensions viscosity on their concentration at 293 K and shifting rate 27 s⁻¹.

The dependences for other shifting rates were similar to that in Fig. 3. The semolina suspension viscosity shows a sharp increase after its concentration exceeds 16 % (see Fig. 3, bottom line) while the same jump occurs for the quinoa suspensions after 13 % (upper line in Fig. 3). Further increase in the disperse phase concentration causes rise in the dough viscosity of 0.8÷1.1 Pa*s for each 10 % of concentration. This is an evidence of the stable coagulation structure based on the cereal particles or aggregates that appear in the system. Therefore, both suspensions are stable against sedimentation and can self-recover after destruction. However, effective homogenization and stirring of such systems at viscosity over 2÷2.5 Pa*s may require too much energy.

Therefore, it can be recommended to keep quinoa and semolina contents in the mixtures below 13 % and 16 % correspondingly. In the case of substitution of semolina with quinoa, this should be done according to the ratio 1 g of semolina for 0.8 g of quinoa.

Further investigation of the highly concentrated mixtures' viscosity showed that it rose with concentration more slowly than it should in the case of complete structure that involves all disperse phase particles. In this case, some particles in the structure become its nodes while the others can get located in the interstices structural space. This distribution is dynamic and some interstice particles can become nodes and vice versa:

Disperse particle (structure node) ↔ disperse particles (interstice space)

The interstice particles also participate in the inter-particle interaction that keeps distance fixed between the nodes even if their influence is less important than that of the node particles.

Low concentrated suspensions exhibit low viscosity but they are unstable and decompose easily and irreversibly. If the concentration is higher than critical, the system's viscosity rises sharply with concentration while the system's stability against external influences decreases. This can be caused by complete filling of all node locations at the critical concentration followed by filling the interstices at further increase in the particles content. Interstice particles cause extra load on the formed structure and lower its stability.

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4. Conclusion

It has been shown that swelling of the quinoa mixtures is more intense because of the higher content of fine-dispersed particles and lowers its water content. Hydrolysis of the quinoa mixtures is also more intense than for the semolina compositions. An initial volume of the disperse phase particles increases with temperature while stability of the formed structures decreases. Microbes' functioning is the most influential factor of the systems' decomposition. The critical concentration of semolina in water suspensions is of 16 % and for quinoa of 13 %. Higher contents cause sharp increase in the systems' viscosity. Interchange between semolina and quinoa should be done according to the ratio 1 g of semolina for 0.8 g of quinoa.

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