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ORIGINAL RESEARCH PAPER

PROPERTIES OF NANOSTRUCTURED CHIA SEEDS AND PROSPECTS OF THEIR APPLICATION IN FUNCTIONAL FOODSTUFFS

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Abstract: The research paper sets out the results of the examination of ion and nanoparticle tracking analysis. The research results show that the chia seed nanoparticles exhibit supramolecular properties and are water-soluble; a nanocapsule medium size is from 214 to 291 nm. That said, the size of chia seed nanocapsules depends on the nature of a carbohydrate shell significantly.

Keywords: *chia seeds, functional products, nanocapsules, NTA method*

INTRODUCTION

Today a lot of foodstuffs are known, which not only meet our physiological need for food but also make it possible to improve a body state significantly in case of their regular consumption. One of such curative food is considered to be chia seeds, which are one of the symbols of the western world. At present these seeds are used both in cooking for making of different dishes and in food industry [1 – 5]. Nowadays chia seeds are also widely used for extraction of bioactive compounds required for the development of functional products [6].

Protein content in chia seeds, grown in different habitats, is from 18.8 % to 21.5 % [7]. The seeds contain vitamins of A, B, E, C groups, which concentration exceeds the one in briar, banana, bog whortleberry and spinach by several times. It is observed that the content of calcium, magnesium and potassium in the seeds is more than in milk. Besides the chia seeds are a potential source of antioxidants; and a higher share of α-linolenoic acid makes them an excellent source of omega-3 polyunsaturated fatty acid (about 65% of oil content) [8 – 10].

Chia seeds are justifiably called curative because one can be cured of different deseases by using them. Today the dishes containing chia seeds are advised for consumption by people having such deseases as diabetes mellitus, memory impairment, a gastrointestinal disorder, neurological disorders, a high blood cholesterol level, a metabolic process pathology and others [9].

Along with the composition a size of capsules containing bioactive compounds is significant for the physiological activity of an organism [11]. The research results of many drug substances show that the reduction in the capluse sizes increases their bioavailability and efficiency [12]. Consequently the bioavailability can be increased by means of decreasing of ingredient particles to micro- and nanosizes.

MATERIALS AND METHODS

The subject of the research was nanostructured chia seeds in different carbohydrate shells. For the experiment, chia seeds (origin: Uruguay) were used, which were ground to a powder. Sodium algenate, gellan gum, carageenan, carboxymethylcellulose and konjac gum were used as carbohydrate shells.

The powder of nanostructured chia seeds was dissolved in water in order to examine the nanocapsule self-organization. A proportion of 1 : 100 of nanostructured chia seed powder under invetigation and water was chosen as the most favorable dilution.

The sizes of nanoparticles were examined by NTA (nanoparticle tracking analysis) by Nanosight LM0 nanoparticle multiparameter analyzer in HS-BF configuration (Andor Luca high-sensitive camera, a semiconductor laser having a wave length of 405 nm and power of 45 kW) made by Nanosight Ltd (Great Britain). The operation of this device is based on a method of Nanoparticle Tracking Analysis, NTA described in ASTM E2834. The following parameters of the device were chosen for measuring: Camera Level = 16, Detection Threshold = 10 (multi), Min Track Length: Auto, Min Expected Size: Auto, a single measurement duration is 215 s; a syringe pump was used.

RESULTS AND DISCUSSION

The obtained results are demonstrated in figures 1-5 and tables 1-5.

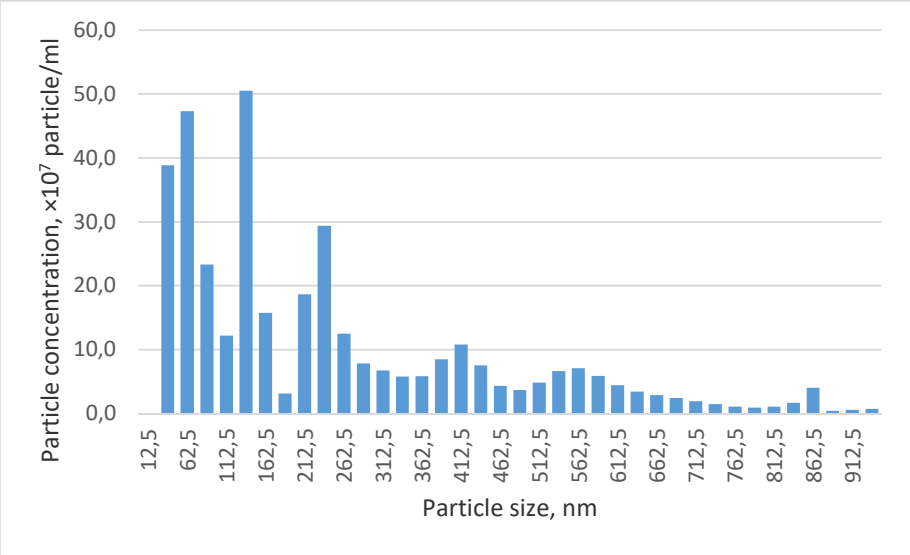

Figure 1. *Particle size distribution in a sample of chia seed nanocapsules in sodium alginate (proportion of core : shell is 1 : 3)*

Table 1. *Statistical characteristics of particle size distribution in a sample of chia seed nanocapsules in sodium alginate (proportion of core : shell is 1 : 3*

Parameter	Value
Medium size [nm]	269.10
D10 [nm]	25.00
D50 [nm]	149.00
D90 [nm]	575.40
Polydispersity index, (D90-D10)/D50	3.69
Total particle concentration, $\times 10^{12}$ particle·mL^{-1}	37.40

Table 2. *Statistical characteristics of particle size distribution in a sample of chia seed nanocapsules in gellan gum (proportion of core : shell is 1 : 3)*

Parameter	Value
Medium size [nm]	213.80
D10 [nm]	31.80
D50 [nm]	136.80
D90 [nm]	446.90
Polydispersity index, (D90-D10)/D50	3.03
Total particle concentration, $\times 10^{12}$ particle·mL^{-1}	11.80

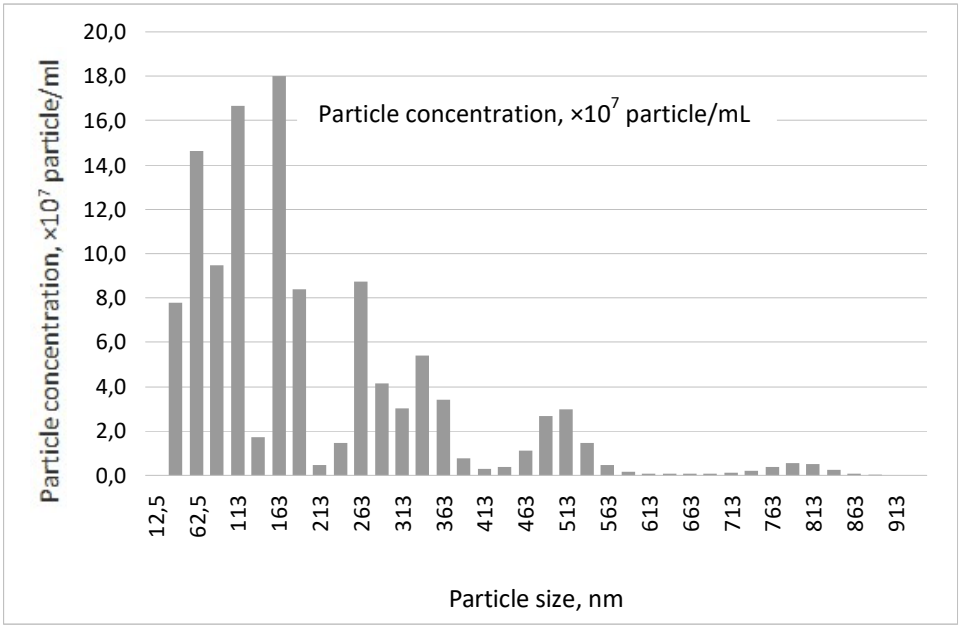

Figure 2. *Particle size distribution in a sample of chia seed nanocapsules in gellan gum (proportion of core : shell is 1 : 3)*

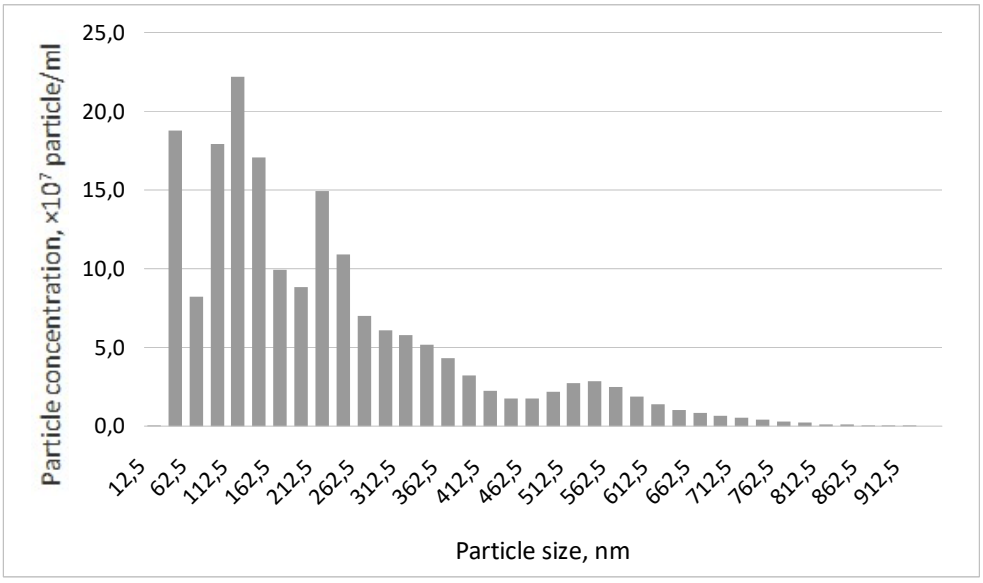

Figure 3. *Particle size distribution in a sample of chia seed nanocapsules in carageenan (proportion of core : shell is 1 : 3)*

Table 3. *Statistical characteristics of particle size distribution in a sample of chia seed nanocapsules in carageenan (proportion of core : shell is 1 : 3)*

Parameter	Value
Medium size [nm]	217.30
D10 [nm]	25.00
D50 [nm]	145.60
D90 [nm]	449.40
Polydispersity index, (D90-D10)/D50	2.91
Total particle concentration, $\times 10^{12}$ particle·mL^{-1}	18.50

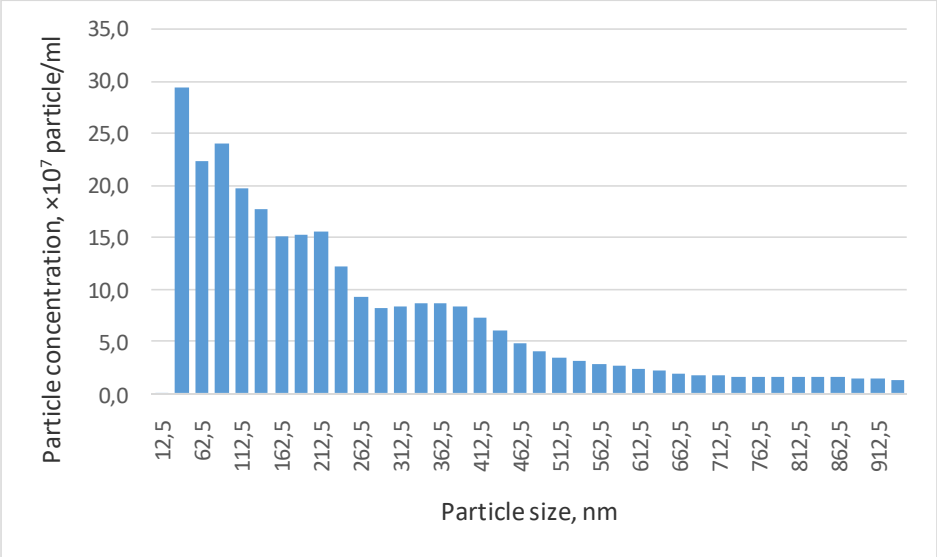

Figure 4. *Particle size distribution in a sample of chia seed nanocapsules in sodium carboxymethylcellulose (proportion of core : shell is 1 : 3)*

Table 4. *Statistical characteristics of particle size distribution in a sample of chia seed nanocapsules in sodium carboxymethylcellulose (proportion of core : shell is 1 : 3)*

Parameter	Value
Medium size [nm]	283.80
D10 [nm]	25.00
D50 [nm]	177.80
D90 [nm]	624.10
Polydispersity index, (D90-D10)/D50	3.37
Total particle concentration, $\times 10^{12}$ particle·mL^{-1}	29.00

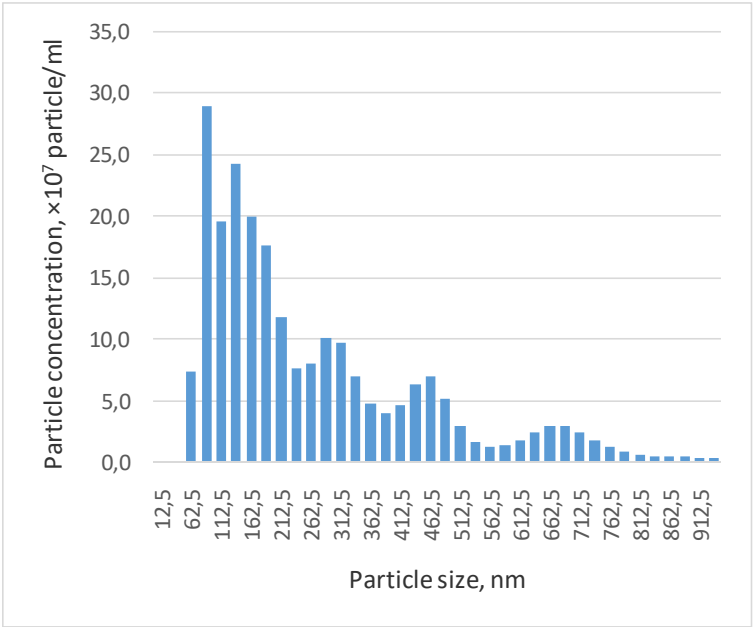

Figure 5. *Particle size distribution in a sample of chia seed nanocapsules in konjac gum (proportion of core : shell is 1 : 3)*

Table 5. *Statistical characteristics of particle size distribution in a sample of chia seed nanocapsules in konjac gum (proportion of core : shell is 1 : 3)*

Parameter	Value
Medium size [nm]	291.20
D10 [nm]	64.20
D50 [nm]	177.40
D90 [nm]	605.70
Polydispersity index, (D90-D10)/D50	3.05
Total particle concentration, $\times 10^{12}$ particle·mL^{-1}	23.70

The obtained results show that chia seed nanocapsule size depends on the nature of carbohydrate shell significantly. One can see from tables 1 - 5 that 10 % of nanocapsules has a size from 25 to 32 nm; the particles only have bigger size of 64 nm in konjac gum. That said, the smallest medium size of nanocapsules is 214-217 nm in gellan gum and carageenan, and it is bigger and makes up 269-291 nm in other shells.
Establishing the relationship between particle size and its reactivity is one of the most important problems of nanochemistry and nanotechnology. The commensurability of the sizes of structural units of a nanophase material with a characteristic size for a particular physical phenomenon (drift length, domain size, etc.) causes a variety of size effects, and the increased surface energy of nanoparticles leads to a meta-stable state of materials in the ultradisperse state.
The surface atoms of the substrate form a force field, which contributes to the formation of atoms and clusters on the surface of the mobiles, and the potential is maximum over the surface of the substrate during crystallization, which leads to a high probability of atom association into the cluster and a low probability of this cluster decay.

CONCLUSIONS

Consequently, taking into consideration the chemical composition of chia seeds and also the sizes of nanocapsules in different shells one might assume that it is reasonable to use nanostuctured chia seeds for making functional foodstuff for the purpose of better digestion of nutritive and bioactive substances.

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