Mechanism of water binding and water content of the nanoparticles of “Magnetofood” food additive

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Abstract

It is proposed the influence mechanism of the nanoparticles (NP) of a polyfunctional “Magnetofood” food additive with the functional groups of the complex proteins of rye-wheat flour.

The nanoparticles of “Magnetofood” food additive interact with the compound proteins at the expense of the coordination links. Under the influence of the NP of “Magnetofood” additive in the structure of compound proteins there are the structural changes: there are the formation of “cluster” type and the electrostatic complexes of biopolymer with the NP “Magnetofood”. The NP of “Magnetofood” food additive affects the association H₂O of lipo- and glucoproteids of the rye - wheat dough. Due to this, the processes of hydration and water content are intensified. This leads to the consumer characteristics improvement of the bakery products.

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Introduction

Bakery products must comply with the quality standards and sanitary standards. Today, the most difficult thing is to find the required quality flour with the help of which it would be possible to slightly improve flour with not very good baking properties.

As a result, bread-making enterprises must use improvers to enhance the quality of flour and correct its deficiencies. Therefore, bread-making industry more often replaces traditional raw materials with cheaper technological powdered raw materials and nutritional supplements, which could increase the nutritional value, enrich a food product with functional ingredients and reduce caloric content.

Dough is a complex hydrophilic colloidal system, composed of the gluten frame, which is filled and surrounded by weakly swollen starch and lipids, sugars and minerals dissolved in it. It was established that lipids, carbohydrates and mineral elements reside in gluten in the chemically bound state – both in the form of adsorption complexes and partially in the form of compounds (glucolipids, lipo- and glucoproteids). At the same

time, starch and shell particles are kept mechanically [1–4]. NP of «Magnetofood» food supplement has high-power energy and chemical potential, and bio-relation to biopolymers, namely, proteins, carbohydrates. Therefore, they bear new functional and technological properties, for example, MRA [5–10].

In order to stabilize the structure of the protein carbohydrate frame and supramolecular solvate associates of the protein-carbohydrate complex of flour, we propose applying the multifunctional food supplement «Magnetofood». «Magnetofood» is an ultra-fine ferrous oxide powder of $\text{FeO} \cdot \text{Fe}_2\text{O}_3$ with a particle size of ~80 nm.

Materials and methods

We studied the effect of NP of the polyfunctional food additive «Magnetofood» on the technological properties, namely moisture-retaining ability of rye-wheat dough. The object of our study is the technology of the ryewheat bread. The food additive «Magnetofood» was introduced in the form of powder when preparing the test flour samples in the amount of 0.10–0.20 % to the mass of flour [TU U 10.8-2023017824-001:2018]. Technology and equipment of food production 65 Under the influence of NP of the food additive «Magnetofood», the structural changes occur in a glucoproteid structure, which are shown in Fig. 1.

Fig. 2 shows formation of solvatocomplexes in the «clusters» of a link of the glucoproteid chain.

An analysis of data in Fig. 2 shows that NP of «Magnetofood» are the active hydrophilic centers along with the ionogenic groups of disaccharide and protein. NP «Magnetofood» activate the formation of solvatoassociates. The content of lipids in wheat flour is (1,5–2,0) %. In flour, lipids are both in the free state and in the form of complexes with proteins (lipoproteids) and carbohydrates (glycolipids). The carboxyl or oxogroups of fats are more polarized and reactive than the alcohol groups of cellulose and hemicellulose. Therefore, under the influence of NP «Magnetofood», lipoproteids and glycolipids undergo structural changes and, when hydrated, can form more stable structures. Fig. 3 shows the process of self-organization of NP from the food additive «Magnetofood» into an electrostatic complex with a lipoproteid stabilized by the electrostatic interaction between atoms and groups.

It follows from data in Fig. 3 that NP of Magnetofood form internal molecular complexes at the expense of coordination bonds with the atoms of nitrogen and oxygen from the remnants of glutamine, proline and 1-linoleyl-2-oleoylglycerol. In addition, there are partial formation of the «clusters» type that make up 30 % of the structured matrix.

Fig. 1. Self-organization of NP of the food additive «Magnetofood» into the electrostatic complex with a link of glucoprotein chain

Fig. 2 Solvatocomplexes in the «clusters» of the glucoprotein chain link

Fig. 4 shows the formation of solvatocomplexes in the «clusters» of the lipoproteid chain link.

Fig. 3. Formation of the electrostatic complex of NP from the food additive «Magnetofood» with the lipoproteid chain link

An analysis of Fig. 4 shows that due to the presence of the polarized NP of «Magnetofood» and «clusters», as well as the system of hydrogen bonds between water dipoles, the accumulation of water is observed around NP of «Magnetofood» and in the «clusters» of the lipoproteid chain, which contributes to an increase in MRA of rye-wheat dough.

Solvatochemical complex NP "Magnetofood" in the "cluster" chain link Lipoprotein

Fig. 4. Solvatochemical complexes in the «clusters» of the lipoprotein chain link

Conclusions

1. The mechanism of interaction between nanoparticles (NP) of the food additive «Magnetofood» and functional groups of complex proteins of rye-wheat flour was established. NP from the food additive «Magnetofood» mostly interact with the complex proteins at the expense of coordination links. Under the influence of NP from the additive «Magnetofood», the structure of complex proteins undergoes structural changes: the emergence of formations of the «cluster» type, as well as the electrostatic complexes of biopolymer with NP of «Magnetofood».

2. The mechanism of influence of NP from the food additive «Magnetofood» on the binding of H_2O by the lipo- and glucoproteins of rye-wheat dough was established. NP from «Magnetofood» modify lipo- and glucoproteins, alter the spatial structure, contributing to the strengthening of hydration and water retention processes. The ionized NP of «Magnetofood» activate the formation of solvatoassociates. The «clusters» of complex proteins contain free water and there emerge the aqua-associates (H_2O is retained by means of hydrogen bonds).

3. The mechanism of interaction between the «Magnetofood» nanoparticles and complex proteins and H_2O molecules in rye-wheat dough system is proposed. Owing to the presence of the polarized NP of «Magnetofood» and «clusters», as well as the system of hydrogen bonds between the H_2O dipoles, the accumulation of water is observed around NP of «Magnetofood» and in the «clusters» of chains of lipoand glucoproteins, which promotes the increased MRA of rye-wheat dough. The «clusters» may retain inter-micellar and intra-micellar water, which is bound by the hydrogen,

dipole-ion, and dipole-dipole bonds to the polarized NP of «Magnetofood» and hydrophilic groups of gluco- and lipoproteids. And, finally, water dipoles may simply participate in hydrogen bonds, without breaking their strength. In addition, lateral branches that appear in the polymeric macrostructure contribute to the extension of main chains, without disrupting their «cross-linking». That facilitates the interaction between macromolecules of complex proteins and dipoles of H₂O and improves the hydration of lipo- and glucoproteids of rye-wheat flour.

Thus, when enriching rye-wheat flour with the food additive «Magnetofood,» its water-absorbing capacity and moisture-retaining ability both increase.

References

1. Substantiation of the mechanism of interaction between biopolymers of ryeandwheat flour and the nanoparticles of the magnetofood food additive in order to improve moistureretaining capacity of dough / Tsykhanovska I., Evlash V., Alexandrov A., Lazariyeva T., Svidlo K., Gontar T. et. al. // Eastern-European Journal of Enterprise Technologies. 2018. Vol. 2, Issue 11 (92). P. 70–80. doi: <https://doi.org/10.15587/1729-4061.2018.126358> Eastern-European Journal of Enterprise Technologies ISSN 1729-3774 4/11 (94) 2018 68
2. Investigation of the moisture-retaining power of rye-wheat gluten and flour with polyfunctional food supplement «Magnetofood» / Tsykhanovska I., Evlash V., Alexandrov A., Lazareva T., Svidlo K., Gontar T. et. al. // EUREKA: Life Sciences. 2018. Issue 2. P. 67–76. doi: <http://dx.doi.org/10.21303/2504-5695.2018.00611>
3. Martins Z. E., Pinho O., Ferreira I. M. P. L. V. O. Food industry by-products used as functional ingredients of bakery products // Trends in Food Science & Technology. 2017. Vol. 67. P. 106–128. doi: <https://doi.org/10.1016/j.tifs.2017.07.003>
4. A review: Modified agricultural by-products for the development and fortification of food products and nutraceuticals / Lai W. T., Khong N. M. H., Lim S. S., Hee Y. Y., Sim B. I., Lau K. Y., Lai O. M. // Trends in Food Science & Technology. 2017. Vol. 59. P. 148–160. doi: <https://doi.org/10.1016/j.tifs.2016.11.014>
5. Current trends in the enhancement of antioxidant activity of wheat bread by the addition of plant materials rich in phenolic compounds / Dziki D., R y o R., Gawlik-Dziki U., wieca M. // Trends in Food Science & Technology. 2014. Vol. 40, Issue 1. P. 48–61. doi: <https://doi.org/10.1016/j.tifs.2014.07.010>
6. Mango seed: Functional and nutritional properties / Torres-Le n C., Rojas R., Contreras-Esquivel J. C., Serna-Cock L., Belmares-Cerda R. E., Aguilar C. N. // Trends in Food Science & Technology. 2016. Vol. 55. P. 109–117. doi: <https://doi.org/10.1016/j.tifs.2016.06.009>
7. Bharath Kumar S., Prabhasankar P. Low glycemic index ingredients and modified starches in wheat based food processing: A review // Trends in Food Science & Technology. 2014. Vol. 35, Issue 1. P. 32–41. doi: <https://doi.org/10.1016/j.tifs.2013.10.007>

8. Ngemakwe P. N., Le Roes-Hill M., Jideani V. Advances in gluten-free bread technology // Food Science and Technology International. 2014. Vol. 21, Issue 4. P. 256–276. doi: <https://doi.org/10.1177/1082013214531425>
9. Products of chickpea processing as texture improvers in gluten-free bread / Bird L. G., Pilkington C. L., Saputra A., Serventi L. // Food Science and Technology International. 2017. Vol. 23, Issue 8. P. 690–698. doi: <https://doi.org/10.1177/1082013217717802>
10. Effect of microalgae incorporation on physicochemical and textural properties in wheat bread formulation / Garc a-Segovia P., Pag n-Moreno M. J., Lara I. F., Mart nez-Monz J. // Food Science and Technology International. 2017. Vol. 23, Issue 5. P. 437–447. doi: <https://doi.org/10.1177/1082013217700259>