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Edible film coatings for the packaging of pre-cooked poultry meat products (frankfurters)

1. Summary

Cooked, seasoned meat pulp stuffed into intestines, i.e., frankfurter is also a popular products in Hungary. For the production of the packaging of the product, large amounts of artificial casings are used, which is peeled off in the households or manufacturing plants, and the casing is then thrown into the waste with no recycling. By using a suitable coating of plant origin, the amount of waste, as well as the cost of production can be reduced, therefore, improving the competitiveness of the product. Of the materials that may be relevant, food industrial use of alginates is quite diverse, however, they are not known as frankfurter casings. In this paper, a new and innovative frankfurter production technology is presented, which was tried at Merian Foods Kft., based in Orosháza. Based on the experience gained during pilot productions, alginate casing proved to be suitable for the preparation of pre-cooked poultry meat products (frankfurter). Therefore, after gaining industrial experience, alginates can present an alternative to the protein- or cellulose-based artificial casings used today.

2. Introduction

Market demands, the technological level and the need to protect the environment all encourage the poultry industry to use such procedures and technologies in the area of processing that, in addition to satisfying market demands, reduce environmental pollution (the emission of harmful substances) to a minimum, in an environmentally friendly way.

Technical innovation is evolving rapidly in the area of food packaging, enabling safe packaging of products, and thus ensuring longer shelf life. Natural and artificial casing of different diameters are packaging materials of primary importance in the production of pre-cooked meat products, including frankfurters. The raw material of currently used artificial casings is either protein or cellulose.

Our experimental work is focused on a new area, alginate-based hydrocolloid technology, the essence of which is that, instead of the current cellophane and digestible casings, products - in this case, frankfurters made of poultry - are wrapped in a casing obtained from algae. The product thus obtained is unconditionally suitable for human consumption and, in addition, the preliminary expectation is that the energy consumption of frankfurter production will to be lower.

The sodium alginate (Na-ALG) intended to be used is obtained from the cell wall of marine brown algae. During the process of gelling, calcium causes water-soluble Na-ALG to convert into a heat-resistant and water-insoluble substance.

3. Literature review

Natural intestines are used as casings for different types of products by both the meat and poultry industries. For laypeople, meat products suffed into intestines mainly mean different kinds of sausages, even though many products in natural and artificial casings are produced by the poultry industry. A popular product, for example, is frankfurter in sheep intestines, having excellent, crunchy kind of sensory properties. Compared to natural casings, the use of artificial casings under industrial conditions is relatively high, because it is difficult to make natural casings uniform, and their tensile strength is low.

The use of natural casings is very widespread both in Hungary and around the world, however, in many cases, it takes a back seat because of high purchase prices. One of the most significant examples of natural

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casings is pig intestines. Pig intestines have been used as casings for centuries, because it is a convenient and cheap solution to use the intestines of the pig during slaughtering. To produce stuffed products, the small and large intestines, the rectum and stomach of pigs are used. Uses of casings of natural origin are summarized in ***Table 1***.

Intestines intended for meat industrial use are classified according to their diameter. Cleaned intestines of identical diameter and length are bundled. Bundled intestines are preserved by salting, drying or by pH reduction. Beef and sheep intestines are processed the same way **[1]**.

Substances that are water-soluble and exhibit properties characteristic of the colloidal state in aqueous media are called hydrocolloids. Hydrocolloids are in fact polymers of colloidal size. The size of colloidal particles ranges from 2 to 500 nm, therefore, they are not visible by light microscopy. Because of their size, hydrocolloids form molecular “solutions”. Since they are typically made of polysaccharides, a special suffix was introduced for them in the English scientific language. Thus, polysaccharide derivatives are designated by an “-an” suffix. According to the rules of grammar, the vowel of the “-an” suffix can change. For example, alg-in (alginic acid derivative), arab-an (arabinose polysaccharide derivative), glyc-an (glucose polysaccharide derivative). However, traditional names of certain substances is so widespread that modern technological language holds on to them, and the names are not expected to change. Such a name, for example, is agar **[2]**.

The advantages of using hydrocolloids are based on their functional properties. These long chain polymers have thickening properties when dissolved or dispersed in water, and lend a viscous effect to the solution. This property is characteristic of all hydrocolloids, but to different degrees. To reach a given viscosity, higher concentrations of certain substances are required, while other substances provide the desired effect in much lower concentrations. One of the reasons for this lies in the differences between the morphologies of the molecules making up the polymers and the chains, as discussed above. Generally speaking, many of the known hydrocolloids can cause visible changes in the viscosities of certain solutions already at a concentration of 1%. Rheological behavior of hydrocolloid solutions, similarly to that of liquid food systems, is related to sensory properties. When preparing different products, the useability of a given hydrocolloid is determined by its rheological properties. Thus, knowledge of the rheological properties of the individual hydrocolloids is helpful in developing appropriate formulas **[3]**.

In addition to thickening, certain hydrocolloids have another important characteristic: under certain conditions, they are capable of forming coherent systems, gels. During gelling, cross-links are formed between the molecule chains, making them capable of encapsulating water molecules in their structures, and so enabling the creation of a flexible structure, highly resistant of various forces **[4]**.

Properties and areas of use of gel particles depend on the type of the hydrocolloid, the mechanism of formation of the structure and the method of processing **[5]**.

Hydrocolloid gel networks are formed by the interlocking and cross-linking of polymer chain, thus creating a three-dimensional structure. There are different types of inter-chain linking mechanisms **[6]**. Typical values of gelling agent concentrations used in foods are summarized in ***Table 2***.

3.1. Hydrocolloids as edible films and coatings

An edible film is nothing more than a thin membrane, used as a coating for different foods, or as an interface between the food and the environment. The best known example for edible packaging is the casing for frankfurters, which need not be removed during either cooking or consumption. The migration of moisture, gases, aroma and fats is prevented by these membranes. For the formation of such membranes, alginate, carrageenan, cellulose and its derivatives, pectin, starch and their derivatives are used, among other things. Since these hydrocolloids are all hydrophilic, due to their nature, coatings made of them have limited moisture retention capacities. However, if they are applied in the form of gels, they can prevent loss of moisture during short-term storage. Based on their origins, edible hydrocolloid membranes are classified into two main categories: proteins and polysaccharides or alginates. ***Table 3*** summarizes **[8]** hydrocolloid materials that can be used widely for the preparation of edible membranes and coatings.

3.2. Alginates

Alginates are primary structural polysaccharides of brown algae. Alginate molecules ensure the flexibility and strong posture of these plants. The most significant type of alga from which alginates are produced is Macrocystis pyrifera, typically found off the California coast, off the southern coast of South Africa, and off the coast of Australia and New Zealand. Another alginate source can be Laminaria hyperborea, Laminaria digitata and Laminaria japonica, all found in the Atlantic Ocean, off the coast of the United States, Canada, Norway and France. Alginates can also be synthesized from certain bacteria, for example, Pseudomonas aeruginosa and Azobacter vinelandii species. In terms of its chemical structure, alginate is a linear copolymer, consisting of β-D-mannuronic acid and α-L-guluronic acid. Alginate itself is not soluble in either water or organic solvents, but its sodium and potassium salts are water-soluble. The biggest food technology advantage of alginates as gelling agents is that they are capable of forming heat-resistant gels with calcium ions **[9]**. The structure of the alginate chain is shown in ***Figure 1***.

4. Experimental results and evaluation

The goal of our experiment was to study the gel-forming properties of Na-ALG in the presence of calcium. Alginates, including Na alginate, form a selective ionic bond with Ca^{2+}-ion, because Ca^{2+}-ion shows a strong reactivity towards Na alginate. As was presented earlier, this improves its heat resistance and, at the same time, the water-solubility of Ca alginate is extremely low, so dissolution of the coating ("intestine") thus prepared is not expected during subsequent technological steps **[11]**.

Materials used for the Na-ALG coating were as follows:

- Drinking water
- Na citrate
- Na alginate
- Citric acid

Materials used for the calcium chloride solution:

- Drinking water
- Calcium chloride

The alginate gel necessary for the experiment was prepared in a cutter. In the first step, citric acid, and then Na citrate was dissolved in half of the necessary amount of water. After complete dissolution of the substances in the water, half of the alginate powder described in the formula was added to the solution, and the cutter was started to chop up the material. After formation of a thick gel, the rest of the water was added, as well as the second half of the Na-ALG powder, and the cutter was started again. Stirring was continued again, until a stable, contiguous gel was obtained, in which the alginate powder was uniformly distributed, not containing any lumps.

From the alginate gel thus prepared, bars of 50 g were molded, and they were placed in three calcium chloride solutions of different concentrations (15%, 20%, 25%).

During the first measurement, alginate bars were kept in the solution as long as the time spent by frankfurters in the floating trough after the filling machine. After the appropriate time, alginate bars were removed and it was found that a film had formed on the piece in the 15% solution, but it had a crumbly structure and could be rubbed off by hand easily. No difference by touch could be established between the bars in the 20% and 25% solutions, and even though the bar in the 25% solution was somewhat harder than the other floated sample, the surface layers of alginate on both bars had solidified completely, and they had not become crumbly. The experiment was repeated three times. Based on our experience it can be stated that the reaction between the alginate mixture and the $CaCl_2$ solution is almost instantaneous, and a stable film is formed on the surface.

After drawing the conclusions from the laboratory experiments, pilot plant productions were also performed to select the optimum $CaCl_2$ solution concentrations and optimal parameters necessary for larger scale production.

Following pilot scale productions, product samples were evaluated with the help of organoleptic testers. Organoleptic tests were performed by 5 trained testers, and samples were evaluated with code numbers.

For the first tests, solutions with a concentration of 25% were used. Alginate was applied to the frankfurter in a nearly 2% quantity, relative to the weight of the frankfurter. When testing the product, the coating that had formed proved to be too hard, it had an unpleasant feeling. It could not be consumed together with the frankfurter, because the coating was too hard, the pulp of the frankfurter „emerged" from the alginate coating.

During subsequent production, solutions with a concentration of 20% were used, and the ratio of alginate to frankfurter pulp was again around 2%. The coating thus obtained proved to be better in sensory testing: it was pliable, but also easy to bite.

To reduce the amount of calcium chloride used and the extent of environmental load, further experiments were performed to ascertain whether solutions with concentrations lower than 20% can provide a uniform alginate gel, but these were unsuccessful, so it can be stated that to establish a coating – artificial casing – of adequate quality, $CaCl_2$ solutions of concentrations of at least 20% must be used. During a later experiment it was determined that no further positive effect was caused by a solution of 22% concentration.

Taking into consideration the composition of the product (pulp), very soon it became clear that product of suitable consistency could not be prepared using the low price category frankfurter formula used in the first experiments. The three frankfurters ('A', 'B' and 'C' formula) described below are mid-range products, with meat contents in the 45%-60% range. The technological processing aids are mixtures containing starch and thickener, an additive containing modified starch, and a mixture consisting of thickener and gelling agent. At the request of Merian Foods Kft., the exact compositions of the formulas are not given when describing pilot plant productions (***Table 4***), however, all the ingredients are listed in detail.

The difference between formulas 'A' and 'B' are in the amount of calcium salt and in the ratio of meat raw materials to additives.

Technological parameters and machine settings were the same in the case of all the products prepared according to the three formulas, in order to be able to obtain a realistic picture about how the quality of the finished product is influenced by the composition of the formula.

For food safety reasons, cooking was performed to a minimum of 72 °C core temperature. Reaching temperatures above 70 °C is important because of the additives in the product, since they exert their effects and stabilize at this temperature – or above. Cooking time is 12 to 20 minutes, depending on the caliber (cross section) of the frankfurter, longer cooking times are not recommended. Products are transferred from the cooking tub to the cooling tub by a conveyor belt, and then they have to be cooled to a core temperature of 10 °C. Cooling times depend on the water temperature and the speed of progression in the tub. It is important to cool the products to below 10 °C as quickly as possible, both because of food safety reasons, as well as to ensure proper packaging state and to preserve taste.

4.1. Evaluation of experimental results and conclusions

The pulp to be filled into the casing has to be prepared in a cutter that can be used under vacuum, in order for the air remaining in the product not to damage the product. If air remains in the pulp, it heats up during the cooking of the frankfurter and the increased pressure can rupture the casing of the product, resulting in holes in the casing.

For the preparation of the alginate coating, a thick pulp with high viscosity is needed. In the case of poorer, low meat content formulas, modified starch has to be used that thickens at low temperatures. Furthermore, calcium salts also have to be incorporated in the pulp, ensuring proper bonding between the pulp and the coating. If they are omitted, the frankfurter becomes too easy to peel. The formulas tried by us contained 0.1%-0.8% calcium salt, but it has to be taken into consideration that the amount of calcium necessary to be added and, thus, the stability of the product casing is also influenced by the calcium ion content of the meat raw material used.

In our experiments, it was characteristic of all three formulas that mechanical properties of the products were close to the expected ones, however, the taste of the products was not found to be satisfactory, therefore, the composition of the basic pulp had to be modified. Average scores for the taste of the modified pulps during organoleptic testing showed a significant improvement, increasing from values of 3.8 – 4.0 and 3.8 to 4.6 – 4.6 – 4.2.

5. Conclusions

The development of new products always involves facing new challenges, and requires great creativity. Dreaming up foods prepared using modern technology seems like an easy task, but translating them into an operational industrial technology is an arduous task requiring sustained hard work. Modern foods have to reflect better-than-usual quality not only in their appearance, but also in their nutritional values and packaging. Our experiments lasted until the conclusion of the writing of this manuscript. Our results so far show that a product capable of commercial distribution can be produced with a sodium alginate coating. However, product development cannot stop. To sustain market and professional success, new ideas and concepts are needed, as well as their experimental and pilot plant testing. Since the casing of the product developed by us is sensitive to overcooking, for successful distribution and keeping them on the market, consumer habits have to be directed as well, within the framework of which they have to be taught the proper heating practice of frankfurters in alginate casings.

6. Acknowledgement

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