Forschungskreis der Ernährungsindustrie e.V. (FEI)

- Project Short Report -

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„ Adjustment of properties of fat-based systems for coatings and barrier layers by influencing fat crystallization“

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Industrial Association: Association of the German Confectionery Industry

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Initial Situation:

Coatings based on a continuous lipophilic phase are often used in the manufacturing of confectioneries and baking goods. Decoration of product surfaces is of interest to prevent material transport, e.g. moisture loss into the environment. Fat-based barrier layers are applied to reduce moisture exchange between layers of different water activity within pastries or fillings. The use of suitable barrier layers contributes to better quality preservation in complex products. So far, it has been well-known that these barrier layers should possess a dense and compact structure to minimize material transport. Normally, fats with a higher melting range including partly hydrogenated fats have been used in such applications. These fats have a firm consistency at room temperature.
Due to the discussion about health effects of partly hydrogenated fats (trans-fatty acids) the food industry has a strong interest to find alternatives to these fats. The challenge in this topic is to obtain the required properties for the barrier layers by suitable combination of fats and fat fractions as well as appropriate processing conditions. However, suitable fat blends and their appropriate processing have been empirically selected, so far. Therefore, this procedure may result in off-specification batches and unwanted quality deviations. Barrier properties not only depend on solid fat content but also on crystal structures. These properties can be influenced by raw materials as well as by processing.
Properties of such fat-based barrier layers and coatings have to be controlled by a suitable combination of fat blends, additives and process conditions to produce a stable and dense structure depending on the individual practical application. So far, such investigations have been carried out in model systems with few and well-defined triacylglycerides (TAG) and were focused on applications in margarine and spreads.
Objective of the project was to generate the scientific-technical base for the aimed setting of barrier properties (minimization of material transport) in fat-based barrier layers as well as the consistency of fat-based coatings. All the blends have to be free of partly hydrogenated fats. To enable a fast industrial implementation of the project results, natural fats and oils including their fractions with different alignments of saturated and unsaturated fatty acids in the TAG should be used in the investigations. Additionally, chain length of the fatty acids was varied by considering appropriate fats and fat fractions.

Research Results:

Different test series were carried out using blends of various fats, oils and fat fractions. Binary blends of a higher melting fat (stearic component) and a lower melting fat or oil (oleic component) were crystallized and characterized with respect to melting behavior, consistency, crystal network structures and barrier properties. Many blends showed incompatibilities of the TAG resulting in lower solid fat contents comparing to the single components. Crystallization conditions were shown to have only a low influence on melting peak temperature but have a large impact on consistency of the solidified blends. Fat blends crystallized under shear during solidification possessed a lower consistency compared to blends after static crystallization (without shearing). A pre-crystallization step at a temperature below peak temperature of the

higher melting fraction with a subsequent solidification without shearing did not result in a higher firmness for the fat blends included in the investigations. Generally, consistency depended on solid fat content but a very broad range of consistencies were found for the same solid fat content.
Structures of the fat crystal networks which were visualized by CLSM differed considerably depending on fat blends and pre-treatment. Inhomogeneous networks with many local compact areas indicated weak consistencies whereas homogeneous structures without compact areas resulted in firmer consistencies of the solidified blends. Structure exponents determined from CLSM images by the method of Detrended Fluctuation Analysis (DFA) correlated with the mechanical firmness of the networks. Therefore, consistency of these systems can be predicted from structure data of the crystal networks. This is also possible for fat blends including emulsifiers like lecithin or sorbitan tristearate.
The barrier properties of the fat blends with respect to moisture migration were characterized using a food model system. It contained a dry layer (cookie), a moist layer (biscuit) and a fat-based barrier layer between these layers. A material transport coefficient describes the barrier efficiency of the layers was calculated from moisture increase in the cookie during storage time. The different barrier effects of fat blends included in the investigations could also be correlated to fat crystal network structures. However, total different network structures are required for a good barrier efficiency compared to those for mechanical firmness. Structures with large interconnected areas of liquid fat result in good barrier properties with respect to moisture migration. Fat crystal networks where the liquid fat is widely immobilized in small structure elements cause higher firmness but inappropriate barrier effects. These relationships could also be modelled by empirical equations.
With respect to the lipophilic additives, it could be demonstrated that addition of sorbitan tristearate results in a significant reduction of firmness of solidified fat blends whereas addition of sugar esters increases firmness but only in blends with the milk stearic fraction as the main component. The effect of additives on barrier properties strongly depends on barrier efficiency of pure fat blends. Addition to blends with good barrier properties decreases their barrier efficiency. On the other hand, barrier efficiency of some fat blends can be distinctly improved by additives if the pure fat blend possesses low barrier efficiency. The influence of solids in the fat blends, like icing sugar or starch, on melting behavior and consistency mainly depends on the type of fat. For instance, solids in a recombined palm fat have a huge influence on its melting properties and consistency whereas nearly no influence in fat blends with milk fat stearic fraction was found.
All in all, structures of crystal networks which are required for high consistency or for good barrier efficiency to reduce moisture migration can be clearly defined based on the project results. Additionally, data which can be used to control these properties for the different types of fat blends are now available for the first time.

Economical Value:

Project results are of interest for manufacturers of confectioneries and for bakers (industry and handcraft), because they have now the means for an improved control of their product properties. Due to the new know-how generated in the project they are able to stabilize the quality of complex composited products for a longer shelf life and to prevent undesired changes due to unwanted moisture transfer within their products, e.g. texture softening.
This quality preservation of their products for a longer shelf life plays an increasing role for the manufacturer of confectioneries and stable baking goods especially if they export their products. New and innovative ideas for product development are often based on complex foods composed of several layers with different water activities and texture attributes. These types of products can contribute to an improved added value for the manufacturers. The prevention or at least reduction of undesired material transport during storage is the main precondition to preserve the quality for the whole shelf life.
The urgent need for a complete elimination of partly hardened in the fat-based barrier layers supports the special project relevance for SME. Due to this elimination requirement, companies cannot longer take usage of their long-term know-how which has been accumulated over the years. The improved knowledge about fat-based barrier layers as the outcome of the project work will contribute to a better availability of the required data for the handling of suitable fat systems without hardened fats.
Therefore, the companies will be able to develop and market high-quality and stable products with a higher added value. Especially the preservation of the high quality for a longer storage time enables an improved production scheduling which reduces manufacturing costs. Furthermore, development cycles for these products can be shortened because expensive storage tests can be reduced and unnecessary trial-and-error-tests will be eliminated. This cuts time and costs in the companies.
Similar effect can be expected for baking companies. Project results will stimulate new product ideas and improved quality also for this business. For example, pound cakes which will have a better moisture

retention resulting in a higher quality for longer storage time can be produced. This will contribute to a higher added value also for these companies.
Additionally, ingredients manufacturer are expected to benefit from the project. Due to an improved knowledge about the relationships in fat-based systems marketed as coatings their clients can be provided with tailor-made solutions for their special needs. This applies not only for the selection of appropriate fats and oils but also for their proper processing.
Manufactures of confectioneries, fine baking goods and ingredients were members of the project industry association. They were informed about current project results already during the project period. It can be expected that the project results will be implemented in the companies within the next few years. This is supported by the fact that all raw materials which are considered in the project are available as commodities for the food industry. The procedures used for the fat processing (crystallization) can be easily implemented in the industrial scale and investment costs can be expected to be low.

Publications (selection)

1. FEI Final Report (2014)

Lectures / posters (selection)

1. Franke, K.; Bindrich, U. (2012) Influence of crystal network structures on mechanical properties of fat-based barrier layers. Köln: ChocoTec 2012, 04.-06.12.2012, Poster.
2. Franke, K. (2013) Influence of fat crystal network structure on mechanical properties of fat-based barrier layers. Solingen: Fine Bakery Forum, 12.-13.11.2013, Oral Presentation

Further Information:

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