COOL INFANT FORMULA

Lengthy warm storage of ingredients and infant formula cause undesirable gastrointestinal effects in piglets, and high heat load during processing of formula leads to unwanted protein modifications

Aim
The project objectives were to investigate how processing and storage affect the quality of ingredients for infant formula (IF) as well as IF itself, and to document that gentle processing improves gut function and health of infants by improving protein bioactivity and reducing processing-induced protein damage.

Background
Organic whey, a byproduct of cheese production, is increasingly in demand for IF despite limited demand for organic cheese. Organic whey proteins can be isolated directly from milk as serum protein concentrate (SPC) by milk fractionation. Milk fractionation may provide organic ingredients for a more efficient IF process with less waste and a reduced CO2 footprint. Proteins in SPC may be more preserved due to more gentle processing conditions. However, the bioactivity and health-derived effects of SPC protein for infants is not previously documented. Development of organic IF with retained protein structure is urgent, especially for infants with an immature gut and immune system, and when mother's own milk is lacking or insufficient

Approach
We combined expertises in processing technology, food chemistry, nutrition and health to generate the understanding of how gentle processing affects protein structure and modifications on a molecular level and correlated this to protein digestibility and bioactivity as well as gut function and health in immature piglets, used as a model for newborn infants.

Heat treatment and storage
Heat treatment and storage effects on protein quality and digestibility were investigated in whey protein concentrate (WPC)-based liquid model IF subjected to either pasteurization, direct ultra-high temperature (UHT) treatment or indirect UHT treatment followed by warm storage for 6 months. Straight after production, the extent of protein modifications induced by direct UHT treatment of liquid IF was similar to the extent induced by pasteurization, whereas indirect UHT treatment caused increased protein modification levels. Warm, prolonged storage triggered reduced protein quality in all samples.

Liquid IF feeding study
Liquid IF was fed to immature, caesarean-delivered newborn pigs to assess bioactivity and clinical outcome. With the increase in the extent of heat treatment and the length of the storage, more structural changes occurred on proteins in IF and more protein modifications were formed, which resulted in digestibility loss. Warm, prolonged storage was the main factor causing adverse gastrointestinal effects in the pigs. Bioactivity of the proteins was affected in line with excess heat treatment leading to increased inflammatory activity. Some protein modifications identified in IF were accummulated in the gut and to some extent in the pigs' kidneys, adversely affecting organ maturation and function.

Protein modifications
Gently processed SPC-based protein ingredients and IF produced thereof, together with conventional WPC-based protein ingredients and IF were evaluated for structural changes and chemical modifications of proteins. Spray drying used in the powdered IF production was mainly responsible for introducing protein modifications. Lactose had a major effect on protein modifications. Adjusting the lactose:protein ratio during processing was efficient for regulating the level of protein modifications. Lactose had a limiting effect on process-induced aggregation of whey proteins whereas absence of lactose resulted in decreased formation of heat-induced chemical modifications. A partial dry

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blending of lactose (30:70, lactose:whey protein) with remaining spray-dried ingredients could be a feasible approach for manufacturing powdered IF with improved protein quality.

Powdered SPC ingredient feeding study

Another feeding study was performed in preterm, caesarean-delivered pigs to assess the physiological impacts of formula with SPC-based ingredients in comparison to conventionally produced WPC-based protein ingredients. The SPC ingredient was well tolerated in pigs and no clinical or subclinical differences were observed compared to the control group receiving conventional WPC. Additional pasteurization by heat treatment applied to the SPC ingredients did not lead to protein modifications affecting intestinal maturation and immunity. Only after additional warm storage at 37 °C and 70% relative humidity for 6 weeks were protein modifications formed to a degree leading to impaired intestinal maturation and function in premature pigs. This underscores that storage of dairy-based formulations at elevated temperature is critical for gut function and health.

How can the industry benefit from this research?

Protein modifications induced by direct UHT treatment of liquid IF were similar to those induced by pasteurization, whereas indirect UHT treatment caused increased protein modification levels. This may encourage liquid IF producers to reduce the heat load applied during processing with resulting reduced energy consumption and CO2 footprint.

Adjusting the lactose:protein ratio during IF processing for regulation of protein modifications is important for ingredient and IF producers that aim to enhance the nutritional value of the products.

The SPC ingredient, formulated into IF by a process with less waste and a reduced CO2 footprint, has a similar tolerability compared to standard WPC-containing IF, when fed to immature newborn pigs.

Projektinfo

related to the Danish Dairy Research Foundation

Title: Effect of UHT and Storage on the Biological Quality of Liquid Infant Formula, part of the project INFANT-I – Tailored Processing of Bioactive Ingredients for High-End Formula
Project manager: Marianne Nissen Lund
Participants: Department of Food Science, University of Copenhagen; Department of Veterinary and Animal Science, University of Copenhagen; Arla Foods Ingredients
Project period: July 2018 – June 2023
Objective: The project aimed to document that tailored gentle processing of organic whey, fractionated directly from milk, and used for infant formula formulation improves gut function and health of infants by improving protein bioactivity and minimizing processing-induced protein damage. The project was a concerted university-industry effort to characterize milk protein deterioration during processing, and adapt processing to ensure less protein damage and improved bioactivity.
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MEJERIBRUGETS FORSKNINGSFOND

Abstract

Our aim was to study how processing and storage affect infant formula quality and health. We found that indirect ultra-high temperature (UHT) treatment and prolonged storage can cause inflammation, while more gentle UHT treatment reduces protein damage and inflammation. Shorter and lower temperature storage conditions improve product quality. Results indicate that indirect-UHT treatment combined with storage induces inflammation in macrophages and preterm piglets, a model for infants. Gentle UHT treatment and optimal storage may prevent disease and improve health care. ●