EFFECT OF ADDITION OF MICROCRYSTALLINE CELLULOSE (MCC) ON STRUCTURE AND FUNCTIONALITY OF EMULSIFIED MEAT BATTERS AND SAUSAGES

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Abstract— **The impact of addition of microcrystalline cellulose (MCC) on structural characteristics of Lyoner sausage batter and quality of finished sausages was studied. To this purpose, Lyoner-style sausages were formulated with four different types of MCC (MAS 11 LS, 11 HS, 17 LS and 17 HS) that differed in manufacturing methods and composition. MCCs were added at different concentrations (0, 0.5, 1 and 2 wt%). Dynamic oscillatory rheology, water-binding capacity, texture measurements, and Confocal Laser Scanning Microscopy (CLSM) were used to determine changes in structure and quality of the meat emulsion matrix. Results showed that all MCC samples increased the storage modulus (G') in fresh sausage batters and the firmness in the finished product. MCC 11 LS and HS also kept water-binding capacity at control batch levels while 17 LS increased and 17 HS decreased water loss. CLSM pictures indicate an increasing disruption of the protein network at high cellulose concentrations (> 2 wt%). Results show that MCC improved firmness of emulsified meat products as long as critical concentrations are not exceeded. MCC-fortified products could thus be formulated at lower protein (meat) contents thereby reducing caloric content of products as well as manufacturing costs.**

Index Terms—**Lyoner-style sausage, microcrystalline cellulose, protein network, fibers, functional meat products**

I. INTRODUCTION

Today, hydrocolloids are widely used in the food industry to improve texture, mouthfeel and water binding of a large variety of food products. Mixtures of hydrocolloids and gums are commonly used to add new textural characteristics to food products and/or to reduce production costs (Williams and Phillips, 2003b). Microcrystalline cellulose (MCC) consists of submicron cellulose particles that are obtained by mechanical treatment. Particles are often agglomerated using carboxylmethyl cellulose (CMC) as a binder to form larger aggregates that can be used in powdered applications. It has been used in different food systems as thickener, gelling agent, emulsifier, stabilizer (e.g. foam), oil replacer in emulsions, and to reduce ice crystal formation in frozen products (Mittal and Barbut, 1993; Penichter and McGinley, 1991; Williams and Phillips, 2003a; Williams *et al.*, 2003b). Applications in industry can be found in dairy products, ice cream, toppings, and confections but also in non-food application such as pharmaceuticals and cosmetics (Holtzapple, 2003). MCC is also widely used as fat replacement system in food (Barbut and Mittal, 1996) due to its ability to mimic fat in aqueous food systems and add to the viscosity, mouth feel and body of the food in a way comparable to the full fat product (O'Connor and O'Brien, 2002). Since MCC is non-digestible, incorporation typically leads to a reduction in the caloric content of foods making it an interesting compound to manufacture diet products. However, while MCC has been studied as a fat replacement systems in meat products, virtually no studies exists that have investigated the precise influence of MCC on the structural and functional characteristics of meat batters (Barbut *et al.*, 1996; Mittal *et al.*, 1993). A better understanding is however needed to select appropriate types and concentrations of MCC for application in for example emulsified sausages. The objective of this study therefore was to study the impact of addition of different types of MCC on the structure, water binding capacity, rheology and texture of emulsified sausages.

II. MATERIALS AND METHODS

Materials: Four commercially available MCC samples (Grindsted MCC MAS 11 LS, 11 HS, 17 LS and 17 HS, Danisco A/S, Copenhagen, Denmark) were used. The MCCs differed in their percentage of CMC and the drying method: MAS 11 LS/HS contained 11.3-18.8 wt% CMC and MAS 17 LS/HS 8.4-13.7 wt%. LS samples were spray dried while HS samples were drum dried. Concentrations studied ranged from 0- 2 wt%.

Preparation of MCC gels. MCC gels containing 10 % MCC in 90 % water were prepared using a bowl chopper (Mado Garant, Maschinenfabrik Dornhan GmbH, Germany). MCC was dispersed into water by slow speed chopping for 1 min. Hydrated (activated) MCC gel particles were then formed by high speed chopping for 4 minutes.

Preparation of sausages: A standard Lyoner recipe including 50 % meat, 28 % fat and 22 % ice was used. Ingredients added to the formulation were curing salt, phosphate, ascorbic acid and Lyoner seasoning. Sausages were manufactured according to the German "Magerbrätverfahren" (low fat meat batter process), chopped (Mado Garant, Maschinenfabrik Dornhan GmbH, Germany), filled (Mado Patron, Maschinenfabrik Dornhan GmbH, Germany) in impermeable casings (Nalo Top, Kalle, Wiesbaden, Germany), heated to a core temperature of 72 °C (Unigar 1800 BE, Ness, Germany), cooled and stored at 2 °C.

Dynamic rheology: A Paar Physica MCR 300 rheometer (Anton Paar Germany GmbH, Ostfildern, Germany) with a plate/plate geometry (25 mm diameter, gap 1.5 mm) was used to determine the storage modulus G' during dynamic oscillation of fresh ready-to-fill sausage batter. A frequency sweep from 0.1 to 100 Hz at 25 °C was performed. Alls samples were measured in duplicates.

Water-binding capacity (WBC): Weighed samples of freshly made batter were put into empty plastic containers, sealed and heated for 45 min in boiling water (~98°C), and then weighed a second time. Total water loss was calculated from differences in measured samples weight before and after heating and expressed as % of initial sample weight.

Texture analysis: Firmness of finished sausage samples (thickness 4 mm, diameter 4.5 cm) was determined using an Instron universal testing machine (Model 1011, Instron Engineering Corp., Canton, MA, USA) with a Kramer Shear Cell. Firmness was measured as force in N/100 g sample.

Confocal Laser Scanning Microscopy (CLSM): Samples of boiled sausages were cut and fitted into slides. Samples were stained with a fluorescence dye specific to cellulose (Calcofluor White, Fluka Chemie AG, Switzerland). A Nikon confocal laser scanning microscope (Nikon D Eclipse C1; Nikon GmbH, Germany) equipped with an argon ion single line laser (488 nm, 10 mW) was used. Pictures were taken at 60x magnification (Plan Apochromat 60.0x/1.40/0.21, oil immersion) and evaluated.

III. RESULTS AND DISCUSSION

Dynamic rheology: Results of the dynamic rheological measurements are shown in **Fig. 1 A-C**. MCC samples were compared depending on concentration of MCC added to the formulation. Compared to the control batch, MCC containing samples had slightly higher or comparable storage moduli G'. Addition of all MCC regardless of type to fresh meat batters increased elasticity and viscosity compared to the control batch. At 0.5 wt% a difference between the manufacturing method for MCC could be observed. MCC 11 and 17 HS batches had lower storage moduli than 11 and 17 LS sample independent of concentration of CMC in MCC samples. With rising concentration of MCC, this difference disappeared until at 2 wt% all MCC batches showed a similar behavior to the control batch. At all concentrations, MCC 17 HS containing samples had the highest storage moduli compared to all other batches.

Water binding capacity: Addition of 11 LS and HS to meat batters did not change the water-binding capacity in the batter (**Fig. 2**). Both samples had similar water losses (5.3-6 %) independent of concentration of MCC and water losses were comparable to those in the control batch (5.7 %). Similar results were previously observed by Barbut and coauthors in low fat sausage formulations (Barbut *et al.*, 1996). Addition of 17 LS and HS however significantly affected water binding capacity. While 17 LS led to increases in water losses (4.6 %, 5.9 % and 8.3 %) with increasing concentration of MCC in the batter, addition of 17 HS had the opposite having, that is the water loss decreased with increasing concentrations of MCC (6.9 %, 5.6 % and 3.5 %).

Texture analysis: Studies on low-fat frankfurters previously reported in the literature demonstrated that low-fat meat batter formulations containing MCC had a hardness comparable to high fat control batch (Barbut *et al.*, 1996). In our studies, texture analysis showed that all Lyoner sausage batches formulated with MCC had a substantially higher firmness (1465-1728 N/100 g) compared to the control batch (1328 N/100 g) (**Fig. 3**). Firmness was also increased with increasing concentrations of MCC. This suggests that MCC is useful in stabilizing a "weaker" batter matrix that may originate from a reduction of for example fat or protein in the matrix. Studies have shown that low-fat sausages formulated with MCC concentrations of about 3,5 wt% have comparable sensory characteristics than the control batch (Keeton, 1991).

CLSM: CLSM images indicated that with high concentration of MCC in batters small pores were formed in the protein network which gave the matrix a foam-like appearance (**Fig. 4**). MCC Concentrations of less than 2 wt% did not have a noticeably structural impact on the matrix that is images resembled those of the control batch. The observation of a formation of pores was independent of the type of MCC added.

IV. CONCLUSION

Addition of MCC at concentrations of 0-2 wt% increased viscosity and firmness of the fresh batter as well as the finished sausage. Water-binding capacity was not negatively affected except in the case of addition of 17 HS and the protein matrix structure of the meat batter was not noticeably altered by the addition of 2 wt% MCC. Above 2 wt%, structural changes occurred in the protein matrix. Results suggest that MCC may be used in meat products to either lower the caloric content and manufacturing cost of products by reducing the required protein or fat content in sausages without reducing firmness and water binding in the sausage. Simultaneously, addition of non-digestible fibers such as MCC may provide a health benefit to the product, since an increased consumption of fibers has shown to reduce risks of gastrointestinal disorders such as constipation, inflammatory bowel disease, ulcerative colitis, Crohn's disease, diverticulitis and colon cancer.

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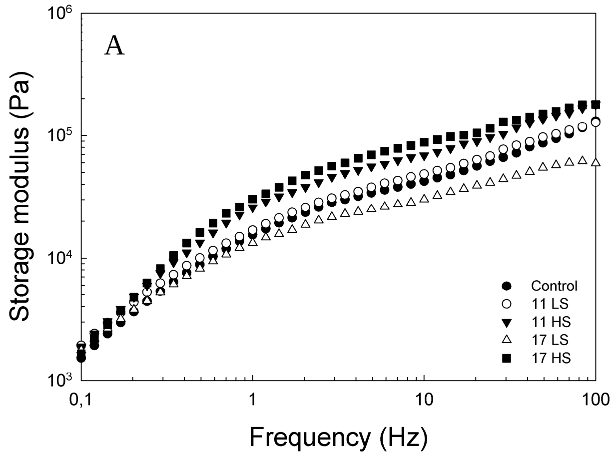
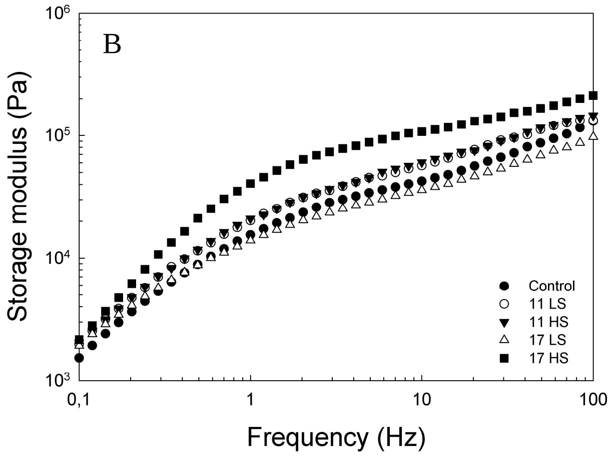
FIGURES





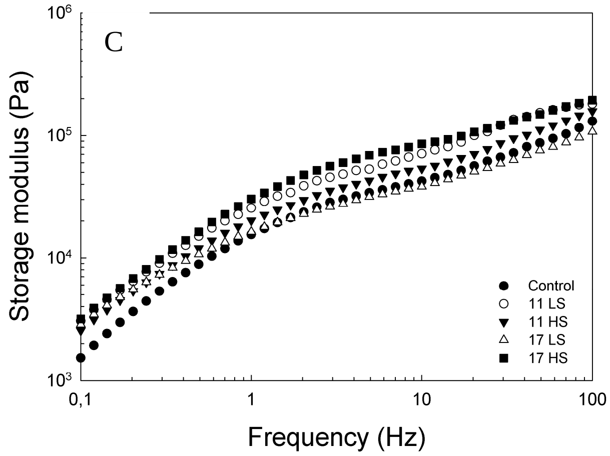


Figure 1: Comparison of all MCC samples at concentrations of (A) 0.5 wt%, (B) 1 wt% and (C) 2 wt%

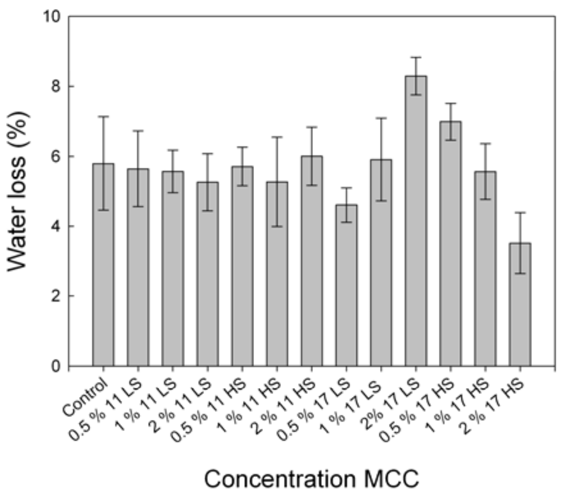


Figure 2: Water loss (%) depending on MCC sample and concentration

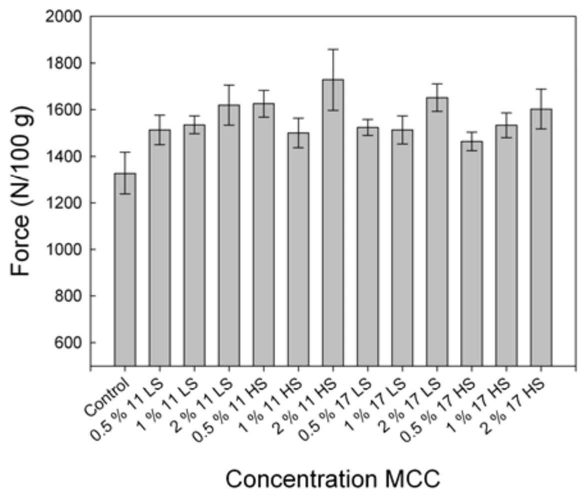


Figure 3: Texture measurements expressed in force needed to cut through sausage slice (N/100 g), comparison of MCCs and concentrations

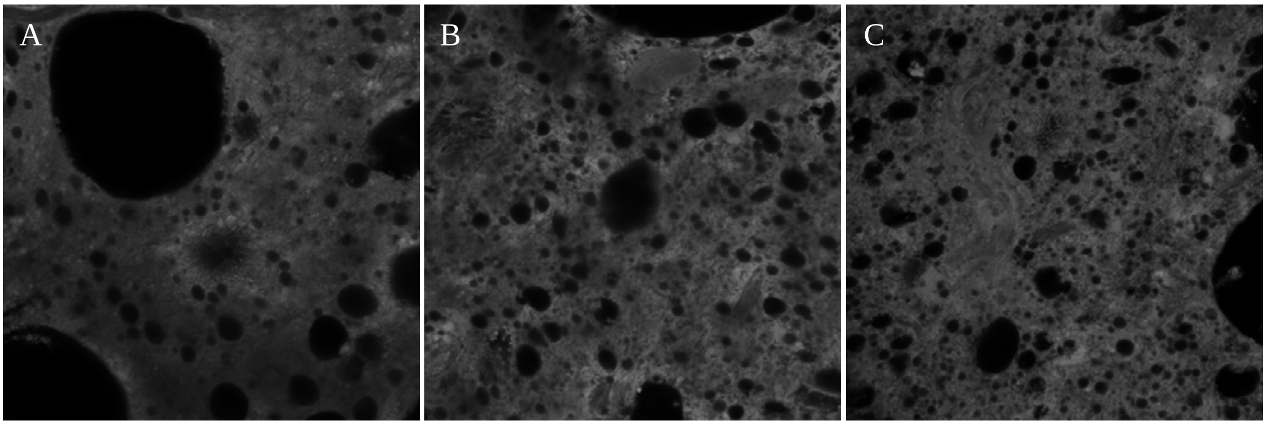


Figure 4: CLSM of finished Lyoner sausages, impact on matrix at an addition of 2 wt% MCC, in comparison with control batch, fluorescence dye Calcofluor White, 60x magnification; (A) control batch, (B) 2 wt% 11 LS, (C) 2 wt% 17 LS

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