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Research Article

Easy Measurement of Different Forces of Water Retention by Hydrocolloids through Water Loss at Same Viscosity

M. Schleißinger and J.J. Schmitt
University of Applied Sciences, Fulda, Germany

Abstract: The aim of this study was to investigate the water binding strength of different polysaccharides (agar-agar, alginate, sodium alginate, carrageenan, cellulose, sodium carboxymethylcellulose, cold swelling starch, guar gum, locust bean gum, pectin, pentosan and xanthan gum). Solutions with similar apparent viscosity were infrared dried with a moisture analyzer at 100°C. Drying times were investigated in order to examine the degree of water binding of hydrocolloids. Agar-agar and cellulose required the shortest drying time and differed significantly from the other tested substances indicating that they bind water in a less tight way.

Keywords: Hydrocolloid, retention, strength, water binding

INTRODUCTION

Hydrocolloids are common additives in baking industry. They play a growing role as food ingredients due to their great potential of applications. In order to achieve synergetic effects of their respective functions, hydrocolloids are commonly used in combination.

Many investigations have been carried out showing the functional properties of hydrocolloids. In several studies their interaction with dough components, mainly gluten and starch, has been demonstrated. They are reported to influence confirmation and hydration properties of gluten and affect gelatinization and retrogradation of starch, leading to a retarded staling of baked goods during storage (Guarda *et al*., 2004; Bárcenas *et al*., 2009; Linlaud *et al*., 2011; Šubarić *et al*., 2011). Addition of hydrocolloids affects bread properties as it contributes to increased specific bread volume and porosity, reduced firmness of bread crumb and improved freeze/thaw stability (Rosell *et al*., 2001; Guarda *et al*., 2004; Bárcenas and Benedito, 2003). Hydrocolloids are also known to act as fat mimetic and gluten substitute (Lucca and Tepper, 1994; Sabanis and Tzia, 2011). Furthermore, they are known to improve wheat dough stability during proofing (Rosell *et al*., 2001; Wang *et al*., 2002). Increased moisture retention of wheat dough in the presence of hydrocolloids has been described by Rosell *et al*. (2001).

However, only few investigations have been carried out concerning the strength of water retention by hydrocolloids. The determination of water binding strength should provide insights to migration properties of water in baked goods as hydrocolloids might provide starch with water during the baking process. This could retard the retrogradation of starch during staling of baked foods. The objective of this study was to examine the strength of water binding by different hydrocolloids. For this, the additives were dissolved in water until they had the same viscosity, representing a comparable strength of water binding for all examined substances. Then those solutions were infrared dried and drying times were investigated. The longer the drying of the different solution to a comparable degree was needed, the stronger the water was bonded by the additive.

MATERIALS AND METHODS

Sample preparation: The commercial hydrocolloids used in this study were: a rod-shaped Cellulose (C) with a mean length of 300 μm, Vitacel, Type: LC 200, J. Rettenmaier&Söhne GmbH&Co. KG, Rosenberg, Germany; Carrageenan (CA), Locust bean gum (L), Xanthan (X), Guar gum (G), Agar-agar (A), Alginate (AL) and Sodium Alginate (SA), Tate&Lyle, Lübeck, Germany; Pectin amide (PC), Herbstreith&Fox KG, Neuenbürg, Germany; sodium Carboxymethylcellulose (CM), Wolff Cellulosics GmbH&Co. KG, Walsrode, Germany; Cold Swelling wheat starch (CS), Type: Toogel, Kröner Stärke, Ibbenbüren, Germany; Pentosan (PS), 80% arabinoxylan extract, Cenaverde BV, Kerkrade, Netherlands.

The substances were dissolved in purified water. In order to ensure comparable conditions for the drying process, viscosity of each solution was adjusted as described below.

Rheological measurements: To determine the apparent viscosity of the solutions, a rotational viscometer (Haake Rotovisco RV20, Haake Messtechnik, Karlsruhe, Germany), equipped with a

Corresponding Author: M. Schleißinger, University of Applied Sciences, Fulda, Germany

Table 1: Examined solutions in purified water at different concentrations (w/w%) with an adjusted apparent viscosity of 0.01 η

Sample	Concentration (%)
Agar agar	7.40
Alginate	0.30
Carrageenan	0.50
Cellulose	1.50
Cold swelling wheat starch	4.80
Guar gum	0.20
Locust bean gum	0.50
Sodium alginate	0.25
Pectin	1.50
Pentosan	9.10
Sodium carboxymethylcellulose	0.20
Xanthan gum	0.30

NV measuring system, was used. The adjustment of apparent viscosity was reached by varying the concentration (w/w%) of a given hydrocolloid in water until a viscosity of 0.01 η was obtained (Table 1). All measurements were performed at room temperature and in triplicate. Shear rate range was 351.0-2702.7 s^{-1}. Apparent viscosity was calculated by the following power law model according to Ostwald-de-Waele:

$$\eta = K \cdot \dot{\gamma}^{n-1}$$

where η, K, $\dot{\gamma}$ and n are apparent viscosity, consistency index, shear rate and flow behavior index, respectively. Apparent viscosity was determined at a shear rate of 583.2 s^{-1}.

Determination of the water loss: Moisture content was determined using a moisture analyzer (Sartorius Moisture Analyzer, Model MA35, Sartorius Weighing Technology GmbH, Göttingen, Germany). 5 g of each sample were distributed on a weighing pan in a uniform thin layer (0.5-1 mm height) and dried at 100°C in the moisture analyzer. Moisture content was evaluated every minute. Drying process stopped automatically when equilibrium moisture content was achieved. Five repetitions were made for each sample. Drying times of all samples were investigated until a moisture content of 42.4% was reached. This ensured that observed drying times did not correspond to the respective total moisture loss of the samples, but depended on the different water binding strengths of the tested additives.

Statistical analysis: Statistical analyses were carried out using the software program Statistica 10 (StatSoft, Inc, USA). One-factor Analysis of Variance (ANOVA) was applied with significance defined at $p<0.05$. In order to determine significant differences between mean values, a post hoc analysis was performed using Tukey test ($p<0.05$).

RESULTS AND DISCUSSION

Figure 1 presents different drying times required by tested samples for drying at 100°C. Water migration conditions of all samples were suggested to be

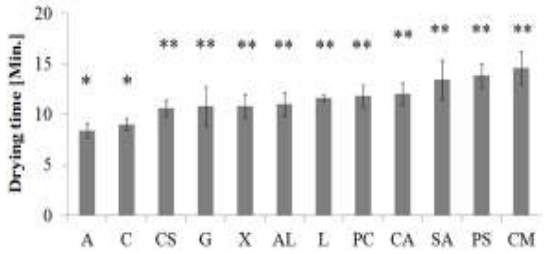

Fig. 1: Times of different hydrocolloids required for drying until a moisture content of 42.4% at 100°C
Samples were: Agar-agar (A), Cellulose (C), Cold Swelling wheat starch (CS), Guar gum (G), Xanthan (X), Alginate (AL), Locust bean gum (L), Pectin amide (PC), Carrageenan (CA), Sodium Alginate (SA), Pentosan (PS) and sodium Carboxymethylcellulose (CM); Values are averages±S.D. of five measurements; Statistical analysis allows division of tested substances into the two groups * and ** with significant differences from each other at $p<0.05$

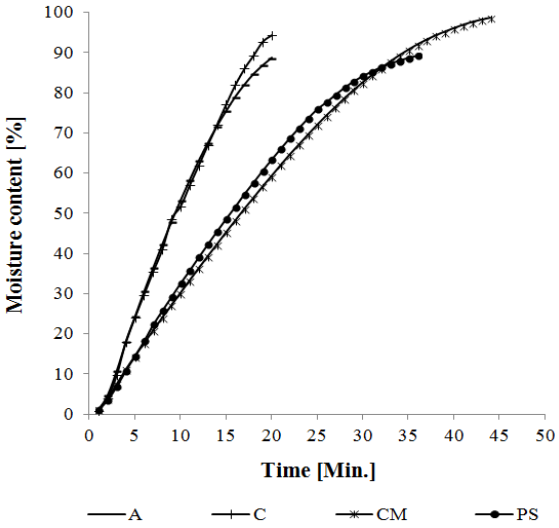

Fig. 2: Drying curves of Agar-agar (A), Cellulose (C), sodium Carboxymethylcellulose (CM) and Pentosan (PS) at 100°C

comparable as drying did not induce any surface effects of the samples. Further, the distribution of the substances on the aluminum weighing pan was thin enough to suggest uniform migration of moisture in all samples. It is therefore hypothesized that drying times were only affected by the water binding strength of the samples.

Agar-agar and cellulose require the shortest drying time and differ significantly from the other solutions. This may indicate weak water retention strength of these substances. Weak water binding strength of cellulose was first found by Leung *et al*. (1976), who investigated water binding forces of hydrocolloids by pulsed NMR. In their work, cellulose was shown to bind water in a less tight way than pectin and sodium alginate. Their findings agree with the observations

made in the study at hand. As drying times of agar-agar correlate with those of cellulose, similar activities concerning water retention strength are supposed to occur in the case of agar-agar. It is assumed that water binding of cellulose and agar-agar takes place through single hydrogen bonding which allows the exit of the water more readily (Chaplin, 2003).

The other tested polysaccharides including cold swelling starch and sodium carboxymethylcellulose present a group of substances which exhibits longer drying times with significant differences to agar-agar and cellulose. However, no differences were found between cold swelling wheat starch, guar gum, xanthan, alginate, locust bean gum, pectin amide, carrageenan, sodium alginate, pentosan and sodium carboxymethylcellulose. Despite the different chemical structures of the mentioned substances, results indicate that they retain water with a similar force. Leung *et al*. (1976) suppose that strong water binding is related to high hygroscopicity of the respective substances. In addition, it is assumed that junction zones, formed by interactions of polysaccharide chains at hydration, lead to a stiff and less flexible structure of the molecules and induce a better binding of water (Chaplin, 2003).

Figure 2 shows drying curves of different hydrocolloids and their different behavior during drying.

The observations made in this study confirm strong water binding of pentosans. Other author's findings also show that pentosans are able to bind water in a strong way during thermal treatment, although investigations of previous studies were conducted in whole wheat dough systems (Li *et al*., 2012).

The results of the work at hand point out, therefore, that measuring of drying times of food compounds with comparable viscosity is a useful and simple tool for determining the strength of water binding of hydrocolloids. The results of the current investigations further indicate that the strength of water retention is similar for most currently food used hydrocolloids (except for agar-agar and cellulose). This expands the choice of hydrocolloids for new food products.

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