The Unbeatable Beet: The Power of Microcellulosic Fibers Unraveled

R. Nolles* and F. Staps**

*Cosun Biobased Products
PO Box 641955, San Jose, CA 95164, USA, robert.nolles@cosun.com
**Cosun Biobased Products, Roosendaal, The Netherlands, francesco.staps@cosun.com

ABSTRACT

A process was developed for rheological functionalization of non-lignin based cellulose from sugar beet pulp. The material obtained is a particulate cellulose material containing at least 60% cellulose, 0.5-10% pectin and 1-15% hemicellulose, and has typical particle dimension within the range of 25-75 µm. The microcellulosic fibers are marketed under the brand name Beta*fib*® MCF and enable novel solutions in particle carrying compounds for fluid water-based compositions. Introduced into liquid compositions the fibers lead to viscosity built up, deliver high zero shear viscosity and a strong shear thinning behavior of the gel formed. As a result of their functionality and stability, the fibers are suitable for use in a wide range of applications, for instance to structure liquid detergents and cleaners, personal care products, oil drilling fluids, cement, paints & coatings and potentially even food products.

Keywords: microcellulosic fibers, sugar beet, structuring of liquids, yield point, particle carrying properties, biorefining

1 INTRODUCTION

It's almost like turning nothing into something. Turning biomass into a new natural resource is obviously considered an advantage at present times with ever growing concerns about overuse and waste of natural resources. The production of the microcellulosic fiber material from sugar beet pulp, as will be described in this article in greater detail, involves processing under generally mild conditions. The result is a unique product with fascinating rheological and structuring properties. Also from an economical perspective, the microcellulosic fibers are attractive as a suspension stabilizing additive for multiple application areas and markets.

2 MICROCELLULOSIC FIBERS FROM SUGAR BEET PULP

Cosun has been able to develop a process for rheological functionalization of non-lignin based cellulose. The plantbased origin of the cellulose in combination with the patented process for extraction, purification and morphological transition of the cellulose enables opportunities for novel solutions in particle carrying compounds for fluid water-based compositions [1]. The parenchymal cellulose based materials are being called microcellulosic fibers and are marketed under the brand name Beta*fib*® MCF.

The microcellulosic fibers are derived from renewable vegetable resources that do not compete with the food chain. In fact, sugar beet pulp forms the remainder after the sugar has been extracted from the beets. The resulting product after processing is a 100% natural biopolymer that has not been chemically modified and is completely biodegradable.

2.1 Composition and dimensions

It is assumed that in the cellulose particles the organization of the cellulose fibrils as it exists in the parenchymal cell walls is at least partly retained. Even though part of the pectin and hemicellulose was removed. Furthermore, the cellulose based nanofibrils are not completely unraveled, i.e. the material is not primarily based on completely unraveled nanofibrils. Instead it can be considered to comprise parenchymal cell wall debris from which substantial parts of the pectin and hemicellulose have been removed as the main constituent (Fig. 1).

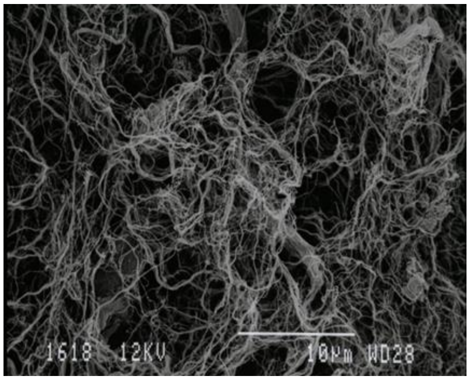

Figure 1: Image of Beta*fib*® MCF

One hypothesis is that at least some hemicellulose or pectin is to be retained in the material to support the structural organization of the cellulose in the particles, e.g. by providing an additional network. Such hemicellulose networks would hold the cellulose fibers together, thereby providing structural integrity and strength to the cellulose particle.

The material obtained is a particulate cellulose material containing at least 60% cellulose, 0.5-10% pectin and 1-15% hemicellulose, and has typical particle dimension within the range of 25-75 µm. The typical diameter of the particles is in the magnitude of tenths of microns.

2.2 Processing sugar beet pulp

The microcellulosic fibers are typically produced by subjecting parenchymal cell wall material to a process wherein part of the pectin and part of the hemicellulose is removed and the resulting material is subjected to shear to reduce the particle size to a certain extent. The parenchymal cell wall material can be derived from a variety of vegetable pulp materials. Particularly good results have been realized with particulate cellulose material produced from ensilaged sugar beet pulp.

Ensilaging of sugar beet pulp typically involves conditions favorable to lactic acid fermentation resulting in lactic acid production and significant lowering of the pH allowing the use of relatively mild chemical and mechanical treatment to obtain the desired material. It is believed that the bonds between cells in the sugar beet pulp that has been ensilaged are weaker than without ensilaging so that moderate shearing is sufficient to separate the cells from one other whilst avoiding the formation of aggregates. This is advantageous in terms of process efficiency as well as product characteristics, which typically will be interrelated.

The composition of crops vary from year to year or even within a harvest due to seasonal influences. The abovementioned process has proven to overcome these seasonal fluctuations and thereby securing a consistent quality of the product manufactured.

2.3 Product form

Beta*fib*® MCF can be provided in concentrated forms, which are relatively easy to redisperse into fluid water-based compositions. The microcellulosic fibers can be treated in a bleaching step without significant impact on the structuring properties of the material. In fact, there are applications in which the bleached microcellulosic fiber network offers better stability. Nevertheless, the most obvious driver for bleaching is to improve the appearance of the resulting products.

3 THE UNIQUE PROPERTIES OF MICROCELLULOSIC FIBERS

Once introduced into a aqueous environment, the microcellulosic fibers show their unique properties. These can be divided into 1) rheological properties and structuring, and 2) suspending or particle carrying properties. Due to the fact that a physical network is build into a fluid water-based composition, completely new formulations become within reach since differences in density become of almost no importance. For instance, not just particles with a specific density larger than the liquid can be carried, but also particles that have a tendency to float can be stabilized by the network.

3.1 Rheological properties

Introduced into liquid compositions the microcellulosic fibers lead to viscosity built up, deliver high zero shear viscosity and a strong shear thinning behavior of the gel formed. Figure 2 shows a high value under no and low shear that the microcellulosic fibers establish next to a strong shear thinning character.

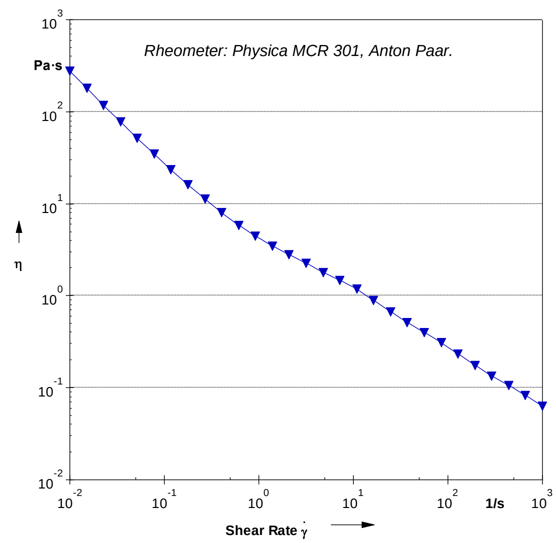

Figure 2: Flowcurve for 1% active Beta*fib*® microcellulosic fibers in water at 20 °C.

3.2 Structuring and stability

The microcellulosic fibers are remarkably effective in preventing migration of suspended solid particles or gas bubbles, in particular the sedimentation of non-colloidal suspended particles, in water-based fluids. In an aqueous environment the fibers form a particle gel and create a physical 3D network that shows superior particle carrying properties. This physical network tends to be stronger than the chemical network that is typically being built by nanofibers. Hence, the zero shear viscosity of a gel structured by the microcellulosic fibers exceeds the zero shear viscosity of gels structured by well-known structurants or viscosifiers like CMC, xanthan gum and guar gum.

Beta*fib*® microcellulosic fibers have a very specific character in comparison to for instance xanthan gum (Fig. 3). The storage modulus (G') shows an elevated value from which can be concluded that the structure build with the microcellulosic fibers is more firm. This is a clear indication of superior particle carrying properties.

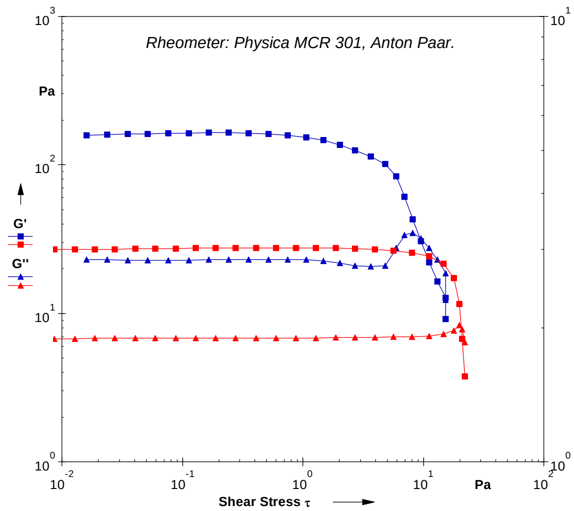

Figure 3: Stress amplitude sweep of 1% active Beta*fib*® (blue) vs. 1% active xanthan (red) in water at 20 °C.

The microcellulosic fibers have been found to retain their functionality as a suspension stabilizing additive under harsh conditions, including high temperatures, at high and low pH values, at high ionic strength and in the presence of oxidizing or reducing agents. Moreover, test compositions structured with the microcellulosic fibers and containing high concentrations of surfactant or electrolytes or high concentrations of acids or oxidizing agents still showed remarkable stability compared to many known structuring agents.

3.3 Particle carrying properties (example)

A benchmark test was conducted to demonstrate the particle carrying capabilities of the microcellulosic fibers in comparison to CMC and xanthan gum. Three gels were prepared with the three different viscosifiers. The viscosity of the gels was set to 1000 cP (or mPa·s) to eliminate the effect of viscosity in carrying particles. The measurements were conducted using a Brookfield viscometer at 30 rpm with a number 3 spindle and at 20 °C.

Both steel and nylon bearings with a diameter of 3/16" were introduced into the fluids and effects were observed. The steel bearings fell through almost immediately for every fluid, due to the relative high density of the bearing. In the gels structured with CMC and xanthan the nylon bearings feel through within 45 minutes. However, the gel structured with the microcellulosic fibers was able to carry the nylon bearing. Even after 48 hours the Beta*fib*® MCF structure was capable of supporting the nylon bearing and suspending it at level height. Figure 4 shows the positions of the different bearings after 48 hours.

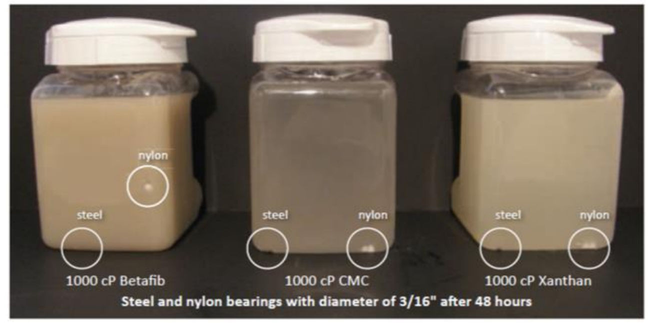

Figure 4: Comparison of particle carrying properties of Beta*fib*® MCF, CMC and xanthan.

4 APPLICATIONS FOR MICROCELLULOSIC FIBERS

Based on the intrinsic properties of the microcellulosic fibers various potential application areas have been identified.

The 3D network built by the microcellulosic fibers is a physical network. The free space within the network offers the ability to 'entrap' particles, like beads, encaps, abrasives or gas bubbles. As a result the density of the materials that have to be suspended in comparison to the density of the liquid is of little importance. Moreover, physical networks have the capability to carry more 'weight'. This property is relevant for fluids carrying abrasives or 'heavy' fluids for oil and gas exploration purposes. Since the fibres are non-ionic to slightly an-ionic they show a significantly lower water holding capacity than many other structurants. This property could be of interest when considering drying profile of ink, paint and adhesives. In combination with the presence of the network anti-cracking is expected. Given the 'virtual fixation' by the 3D network, suspended materials will sink nor float during rebuilding of the network. As a consequence, fluids remain homogeneous during the application of shear and onwards in time after shear is released. This will improve the anti-sagging properties of paints and coatings.

Because of the fact that purified cellulose is a rather inert material, liquids that are structured with the microcellulosic fibers can easily deal with high or low pH. This allow applications in toilet bowl cleaner or alkaline industrial cleaners. The temperature resistance of the material enables use for deep well oil and gas drilling.

The sustainable profile is excellent since the fibers are derived from an agricultural sidestream, are not modified or derivatized and are 100% biodegradable. Hence, suitable areas of applications are product categories with sustainability claims. Examples are home and personal care products, or areas where the product potentially ends up in the environment (oil and gas exploration). The fact that the microcellulosic fibers are an all natural product, opens up opportunities for use as a structurant in personal care products. In addition, because the material is derived from sugar beet pulp, it has great affinity with many food and feed ingredients. And the temperature persistence enables the use in applications like bakeproof jellies. However, Betafib does not have a food grade status yet.

Based on the above, it can be concluded that the microcellulosic fibers are potentially suitable for use in a wide range of applications for which structuring and rheology properties are important. In addition, the physical network built by microcellulosic fibers may be suitable for rheological as well as reinforcement purposes in for instance (ceramic) foams and dry mortars.

5 BACKGROUND INFORMATION ROYAL COSUN

Royal Cosun is a Dutch agro-industrial cooperative. Our ambition is to optimally use vegetable raw materials. We manufacture ingredients for food, non-food applications and the chemical industry. In addition, Royal Cosun is a proud partner in Pulp2Value governed by the Bio-Based Industries Joint Undertaking, which is a new € 3.7 billion Public-Private Partnership between the European Union and the Bio-based Industries Consortium [2].

As member of the Pulp2Value project Cosun Biobased Products has an extensive R&D program in place to develop a production processes and applications for microcellulosic fibers, L-Arabinose and galacturonic acid.

REFERENCES

[1] Stabilization of suspended solid particles and/or gas bubbels in aqueous fluids; G.P.F.M. van Engelen, G.A. van Ingen, C. Meeuwissen and R. Nolles; WO 2014142651-A, Sep 2014

[2] PULP2VALUE, Processing Underutilised Low value sugar beet Pulp into VALUE added products, http://pulp2value.eu/, Mar 2015