

## CELLULON™ Fermentation-Derived Cellulose – Towards Sustainable, Stable Liquid Laundry Detergents and other Home Care Products

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### ABSTRACT

The trend to develop products using sustainable raw materials continues to gain momentum in many areas including home and personal care applications. This presents the challenge of finding suitable ingredients and developing formulations that meet these demands, and yet still provide the performance and experience the consumer expects. Furthermore, environmental regulations around many synthetic products and increasing consumer pressure to reduce the environmental impact of the products they use amplifies these formulation challenges.

To meet these challenges, formulators may have to consider many alternative materials. As an example, in liquid laundry detergents, using more insoluble particles such as decorative beads, opacifiers, active materials, etc., requires a method to provide suspension and stabilization. Using nature-based solutions to achieve this has previously been problematic. It is especially difficult in highly concentrated surfactant systems due to compatibility limitations and the need to avoid adversely affecting the viscosity and pour properties of the product. In the case around alternative opacifiers in detergents, current opacifier technologies are essentially self-stabilizing,

but alternative opacifiers (such as minerals, clays, waxes, etc.) often require some mechanism to stabilize them and keep them homogeneously distributed.

CELLULON™ Fermentation-Derived Cellulose (FDC) technology can help meet and overcome these challenges. Cellulose is common in nature. Chemically identical to plant-derived cellulose, FDC is produced by fermentation resulting in a unique and readily biodegradable form of cellulose, which offers properties not possible with other sources of cellulose. As a consequence of being produced in a bacterial fermentation process, the cellulose fibers possess a very fine diameter and exist as a three-dimensional, highly reticulated net-like structure that gives a very high surface area-to-weight ratio. This three-dimensional, net-like structure allows the FDC to create a true yield value at low concentrations in a formulation, even those with little or no water, and so provide a mechanism for reliable structuring of liquids and stabilization of components with minimal or no impact on the finished product's viscosity and dispersibility.

## BACKGROUND

New trends occurring in the homecare market are driven by consumer demands, social responsibility and regulatory pressures. One key trend that touches all three of these parameters is the growing interest in sustainably sourced, biodegradable materials that are more sensitive in their impact on the environment, both in terms of production and when they are used and moved out into the wider environment.

Options to replace petroleum-derived materials with those derived from sustainable sources such as crops already exist in the market. Although a partial solution, it still doesn't address a product's chemistry, which may not be biodegradable or have other environmental impact. For example, choosing polymers containing ethylene derived from crop-based feedstock is avoiding the use of petroleum resources, but the final product may still not be biodegradable. The use of minerals as opacifiers could still lead to potential issues. These require other components to enhance product performance, perception and sensory attributes that will need to be stabilised in the surfactant media. With upcoming environment-related regulations, ingredients' biodegradability becomes just as important as being nature-based.

Another trend in homecare is to reduce waste by creating more concentrated products and trimming down package size as well as the amount of plastic packaging used. The popular laundry unidose pods could be regarded as the pinnacle of this trend. Add to this the need to differentiate in a competitive market through enhanced performance and visual product properties, and the stabilisation of materials in the liquid matrix becomes key.

A wide range of nature-based suspension aids can be considered (e.g., xanthan gum, carrageenan, various cellulose-ethers, as well as natural clays) but there are limitations to their use. Xanthan can provide excellent suspension in many personal care

surfactant-based formulations, but it cannot recreate the overall rheology that is generally preferred in these formulations and that people are used to due to its high pseudoplasticity. In addition, the use of salt-induced surfactant thickening, in combination with xanthan gum or most other biodegradable viscosity modifiers, often leads to a hazing of the formulation and subsequent phase separation or precipitation of the suspension aid. There are also limits to how concentrated the products can be made before these water-soluble, nature-based products start to precipitate out of solution and cause phase separation, which is an issue in the more concentrated home care products.



In recent years, the trend to improve the fragrance experience in laundry care has been evolving thanks to suspension aids – from increasing the loading of fragrance to the inclusion of encapsulated fragrances homogeneously distributed. Today, as the market is also replacing traditional self-stabilising products such as synthetic opacifiers with biodegradable alternatives, the challenge remains to sustainably suspend them. In short, the technical challenge to provide reliable suspension in a wide range of surfactant-based formulations in a sustainable way, has been largely unsolved. Therefore, there is a critical need for a new nature-based suspension aid that provides

## CELLULON™ FERMENTATION DERIVED CELLULOSE FDC, A NATURE-BASED AND BIODEGRADABLE TECHNOLOGY

Such a product is now available: CELLULON™ Fermentation-Derived Cellulose. The ingredient is produced in a dynamic fermentation process using the bacterium, *Komagataeibacter xylinus*, the same organism that is used to produce the translucent, jelly-like food known as nata de coco that is popular in many Asian countries (Figure 1). Being a fermentation product, FDC offers a highly attractive sustainability profile. Figure 2 summarizes the manufacturing process with the bacterial fermentation

- Excellent biodegradability
- Reliable performance
- Low cost-in-use
- Exceptional compatibility with high surfactant and surfactant-thickened formulations

The ability to provide suspension properties without adversely affecting other parameters such as the pour viscosity. process converting crop-derived, renewable nutrients into the cellulose. This is then recovered and converted via a proprietary process into a useable product that is based on water, sustainably sourced (RSPO) glycerine and co-agents from sustainably produced sources.



Figure 1: CELLULON™ Fermentation-Derived Cellulose is produced by the same organism that is used to make nata de coco food products sold widely in Asian countries.

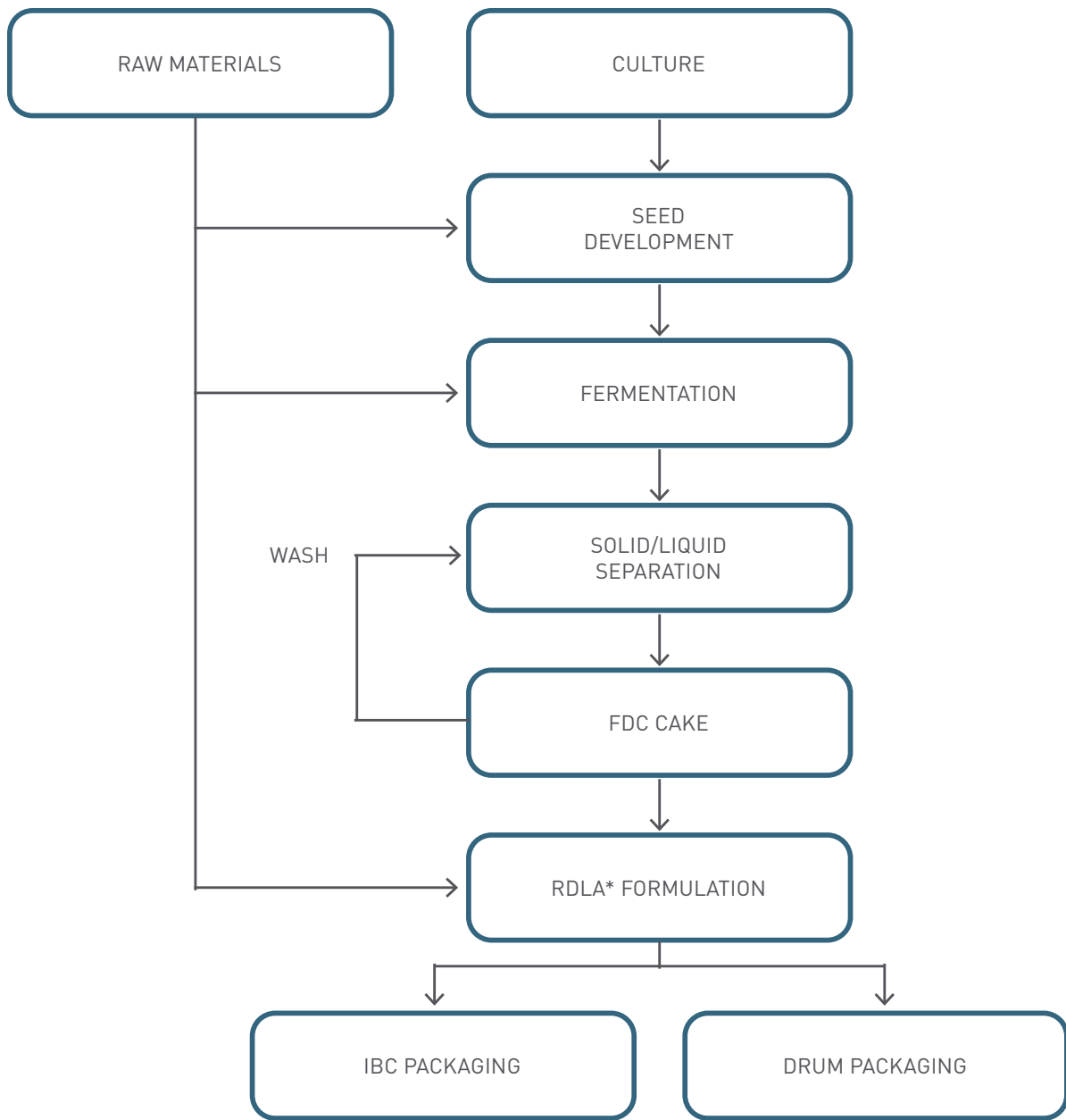


Figure 2: Outline of the process to produce readily dispersible liquid cellulose products.  
 \*RDLA: Readily Dispersible Liquid Activate

FDC is not only made from natural resource but is also a readily biodegradable technology. Tests for biodegradability were conducted at independent laboratories using the OECD 301B method, which is designed to provide a screening of chemicals for ready biodegradability in an aerobic aqueous medium. Ready

biodegradability is achieved when 60% of the total theoretical carbon dioxide from the material is removed within a 10-day window during a test that lasts 28 days. FDC meets the requirements of ready biodegradability by OECD 301B by day 8 of the test and well within the 10-day limit.



## FDC, AN INSOLUBLE NET-LIKE STRUCTURE PROVIDING CONSISTENT PERFORMANCE ACROSS MEDIA

FDC produced by *Komagataeibacter xylinus* is chemically identical to plant-derived cellulose, however the FDC fibers are much smaller in diameter. This leads to a far higher surface area by weight of the cellulose. For example, typical fiber diameters for plant-derived cellulose range from about 30 to 300µm whereas the fiber diameter for FDC is about 0.1-0.2 µm (Figure 3). This smaller fiber size means that a given weight of FDC has up to 200 times more surface area than other forms of cellulose.

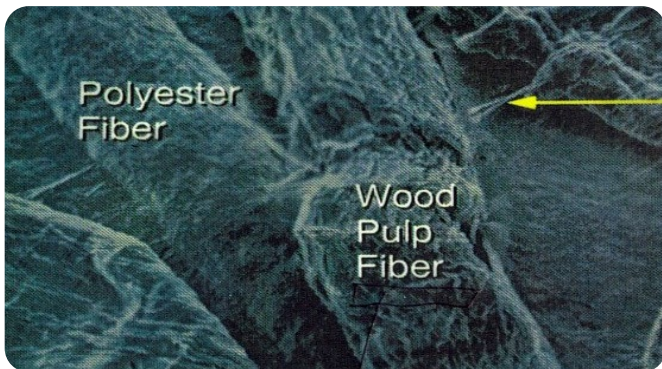
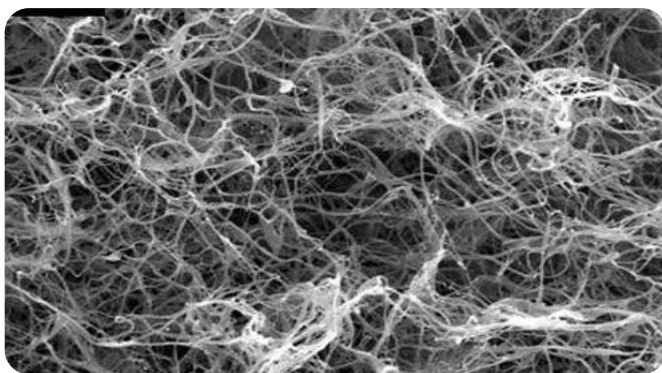


Figure 3: An electron-microscope picture of FDC with its net-like structure and an electron microscope comparison of the FDC fibre size vs. other common fibres.

### So, what does this mean?

- The increased surface area translates directly to greater efficiency in use
- FDC creates a very fine, net-like, three-dimensional network when dispersed in the surfactant-based formulation, thus creating stability in the system it is added to, via a yield stress.
- It is this net-like network structure that differentiates CELLULON™ Fermentation-Derived Cellulose from other cellulose forms.

### In addition, as it is not water soluble:

- FDC's performance does not depend on the water content of the system it is added to
- FDC does not thicken or add to the perceived viscosity at the typical use levels used for suspension
- FDC is compatible with high levels of salts and surfactants that would cause most water-soluble polymers to precipitate.
- FDC is insensitive to many factors impacting water-soluble polymers such as temperature, shear, salt, pH, but also it is far less susceptible to acids, bases, oxidizers and reducing agents, as these cannot attack the individual linkage points as readily as when polymers are fully solubilized.
- FDC is much less susceptible to cellulose enzyme degradation compared to water-soluble cellulose derivatives (e.g., CMC, HEC, etc.) thanks to its insoluble nature and net-like structure making any enzyme degradation much slower to manifest.

## HOW SHOULD FERMENTATION-DERIVED CELLULOSE BE USED?

The fine, net-like structure is unique to FDC. It is effective at creating a true yield stress allowing particles to be suspended indefinitely, so long as the force (stress) required to suspend them is less than the yield stress developed by the FDC network (yield stress is a measure of the force required to initiate flow in a gel-like system). Very low concentrations of FDC are needed in the formulation to create yield stress: FDC is therefore an affordable suspension aid but also does not contribute significantly to the pour viscosity of the formulation. This adds suspension properties to a formulation without changing the perceived viscosity of the final product. In essence, the suspension properties of FDC are largely decoupled from viscosity effects. Formulations can be designed that range from water-thin, such as in a suspending foaming handwash, to honey thick, such as in a surfactant-thickened bodywash. In this latter case, it is FDC's high compatibility with salt-induced surfactant thickening that is unique among nature-based polymers.

In summary, the unique yield stress properties imparted by FDC can provide excellent stability to a wide variety of surfactant-based formulations. These formulations can be highly concentrated (from typically 5% to 45%) and even some pure surfactant and non-aqueous formulations are possible with the correct grade of FDC.

The commercial forms of CELLULON™ Fermentation-Derived Cellulose are readily dispersible systems of activated solutions of FDC in water with other added components (see figure 4). The "activation" or fine dispersion of the FDC is performed during manufacture and is required to properly extend the FDC network for maximum performance and efficiency. The product has been designed to disperse easily in most surfactant-based formulations, with simple bulk mixing being usually all that is required to use CELLULON™ Fermentation-Derived Cellulose. This important dispersibility property is due in part to the addition of a "co-agent", which creates a repulsive

charge between the cellulose fibers and helps prevent flocculation, particularly in higher water formulations. Depending on the system in question, such as surfactant types, water content and other components, the amount and type of co-agent may vary. Thanks to a long experience in fermentation-derived cellulose CP KELCO is able to recommend the best performing grade of the product for any particular system.

Further development of the product range is ongoing to expand the compatibility and potential use of the FDC concept: it is even possible to activate FDC in non-aqueous media and offer a readily dispersible FDC grade suitable for no/low-water systems.

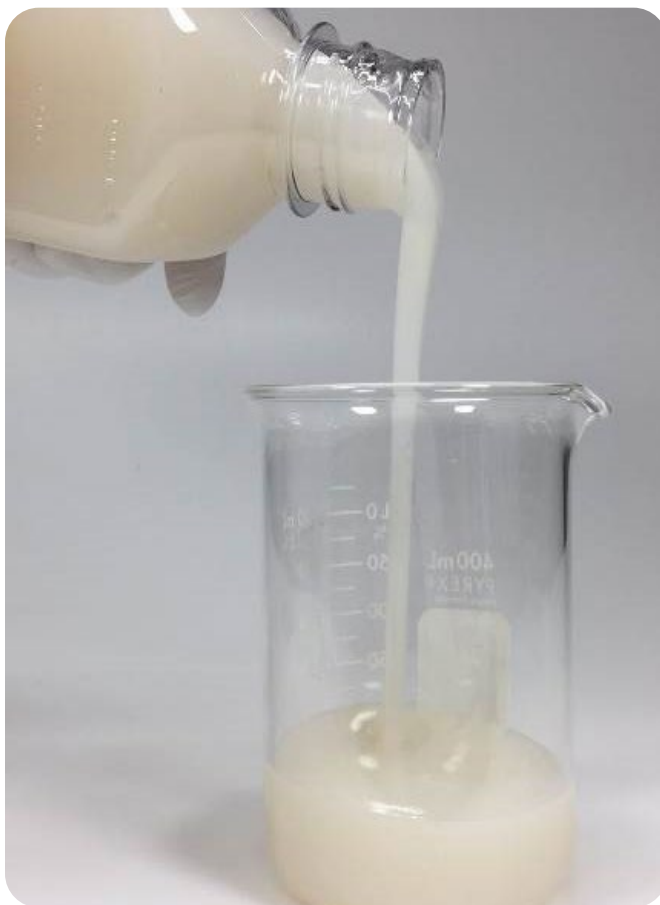


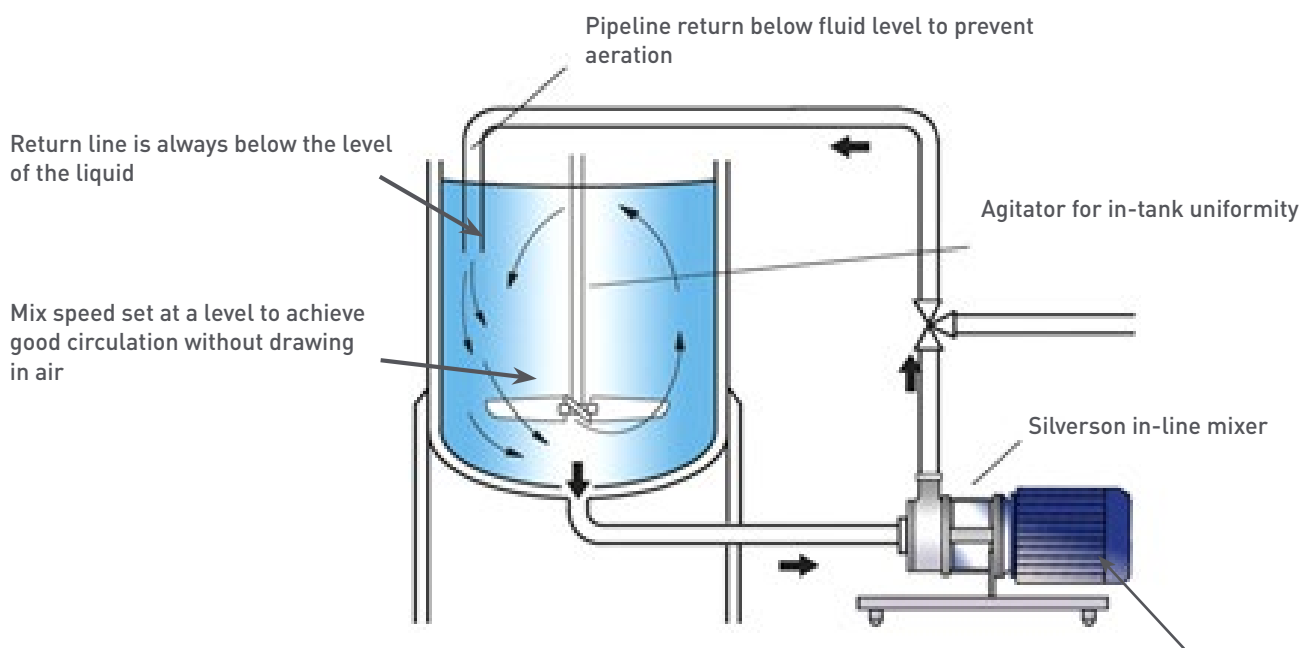
Figure 4: CELLULON™ Fermentation-Derived Cellulose comes ready to use and does not require pH adjustment or high shear mixing to be functional. Use levels range from 0.5% to 5% depending on the formulation and what is to be stabilized

Being readily dispersible, the product can be used "as-is" with no pH adjustments required. Order of addition is not necessarily critical and can be optimized depending on the procedure for final product preparation. For example, the surfactant base may help in the effective dispersion of the cellulose network, or it may be possible to disperse first in water with higher shear to speed up dispersal, so long as other components are then added relatively quickly afterward. The options for any given situation and circumstances can be discussed and optimized.

In the manufacture of many laundry and homecare surfactant-based products, it is often convenient to add FDC as one of the last ingredients.

Once added, it will quickly begin providing suspension capabilities to the formulation and care may be required to avoid trapping air bubbles. One way of achieving efficient dispersion of the FDC and prevention of air is to use an in-line mixer with a recirculating line like the one shown in Figure 5.

In this way, FDC can be incorporated very gently into the bulk mixing tank to prevent air but as it passes through the in-line mixer, full dispersion of the FDC is achieved very rapidly. If the in-line mixer is of a rotor-stator design, one pass may be enough for full dispersion and maximum yield stress.



In-Line mixer could be as simple as a centrifugal pump with a high speed impeller but an in-line shear device will guarantee dispersion in one pass.

Figure 5: Optimal mix design to disperse CELLULON™ Fermentation-Derived Cellulose while preventing air incorporation (Graphic source: Silverson Machines, Inc.: used with permission)



## FDC, UNPRECEDENT LIQUID STRUCTURING AND PARTICLES SUSPENSION

CELLULON™ Fermentation-Derived Cellulose can provide stability at very low concentrations, which has a wide range of benefits in addition to cost-in-use and sustainability. In some systems, approximately 3% of the readily dispersible, activated FDC can achieve yield stress values of around 0.7-1.5 Pascal (measured using static yield stress techniques) depending on the formulation (see Figure 6). The yield stress increases with use level at a factor of about 1.5. The yield stress triples as the FDC concentration doubles.

In some liquid laundry systems, concentrations below 1% generated sufficient yield stress to give long term stability of encapsulated fragrances. The yield value required will depend upon what is being suspended but most fragrance encapsulates and pearlescents can usually be stabilized with a yield stress of less than 0.0.1 Pa. This equates to a CELLULON™ FDC use level of 0.5% to 1% in many formulations. Most decorative beads can be suspended with a yield stress of 0.6 to 1 Pa, which would equate to about 1.5-5% CELLULON™ FDC. Opacifiers, depending on their concentration, size, and density may be stabilized with as low as 0.5% CELLULON™ FDC.

These low-in-use concentrations allow CELLULON™ FDC to be used in formulations where transparency is required. Even though the FDC fibers are insoluble, high clarity can be achieved with the low use levels combined with overall refractive index of the formulation (Figure 7). For most surfactant-based fabric care formulations, the index of refraction is relatively high (e.g., 1.35-1.42) therefore the fibers become largely transparent (cellulose has an index of refraction of 1.5) except for perhaps a slight hazing.

Identifying which grade is best for any given formulation is a relatively simple process: the best grade is that which gives the highest yield stress at any given concentration and under the mix conditions available. If proper dispersion was attained, the yield stress should not significantly change if mixed under strong mixing conditions. The yield value should be stable or modestly increasing with time. Once the best grade is identified, its concentration can be optimized. This article focuses heavily on the application of FDC in laundry and homecare products, but its valuable properties will also make it useful in a wide variety of related applications and formulations, providing good suspension at very low use levels and without creating high pour viscosity.

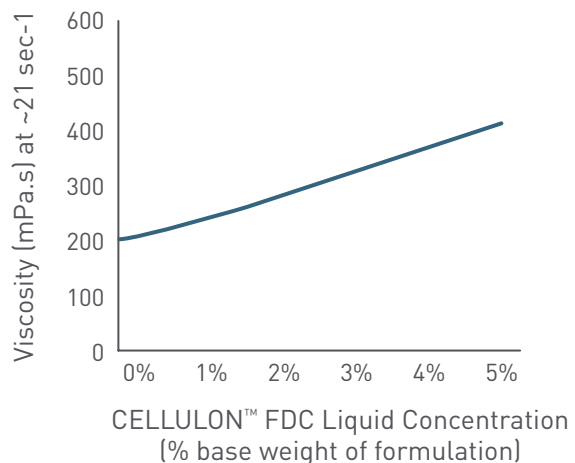
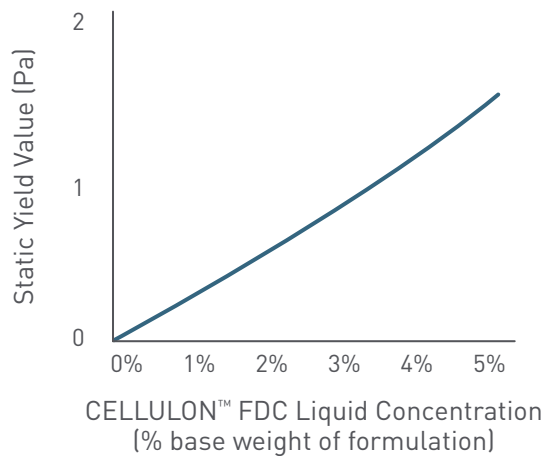


Figure 6: Yield stress and Pour viscosity vs. FDC in a premium, concentrated liquid laundry detergent (Static yield stress values obtained using a Brookfield® DV-III Ultra viscometer (RV or LV) with EZ-yield software, 0.05 rpm, #71 spindle)

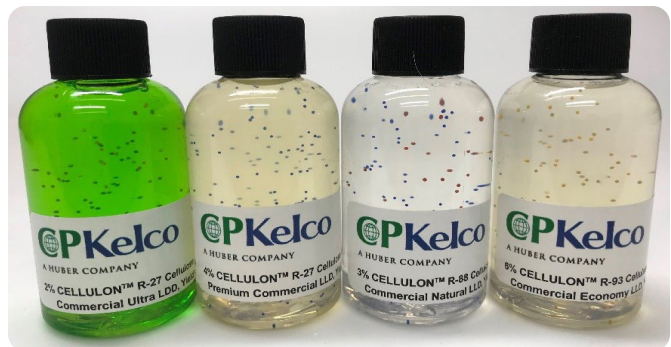


Figure 7: Examples of liquid laundry detergents and a hand dish soap incorporating different grades of CELLULON™ FDC. The low concentrations needed and the high index of refraction result in excellent stability with little to no effect on product clarity.



## CONCLUSION

As consumer trends push the laundry and home care markets towards more environmentally friendly formulations and practices, these industries will need an alternative technology to provide reliable suspension. Fermentation Derived Cellulose is a powerful option for both performance and increased sustainability, offering excellent suspension properties, low cost in use, and due to its insolubility, unmatched limits of compatibility. Its three-dimensional net-like structure enables FDC to structure liquids, suspend perfume microbeads at inclusion levels as low as 0.5%-1.5% "as is", and stabilize opacifiers and any insoluble/non miscible ingredients with inclusion levels that will depend on the density difference between the media and particle size.

Various grades of CELLULON™ FDC are available: the grade choice is especially influenced by the active surfactant level in the formulation. The efficiency of FDC generally increases with higher surfactant levels. For example, CELLULON™ R-93 FDC is recommended for low surfactant formulations such as economy liquid laundry detergents and household cleaners (5%-15% active surfactant levels) whereas CELLULON™ R-88 FDC and CELLULON™ R-27 FDC will be respectively preferred for premium liquid laundry detergents and for concentrated hand dishwashing liquids or concentrated liquid laundry detergents (20% and higher active surfactant levels). For even higher concentrations, other FDC grades under development are available.

### Winner of the Port of San Diego 2018 Green Business Network Award for Waste Management

In 2018, CP Kelco launched a quest to improve the sustainability of its business, focusing on finding recycling or reuse outlets for all waste streams and a commitment towards zero waste. One of the largest efforts took place at its San Diego facility. Employees found a local tree nursery nearby that could utilize the food waste byproduct as compost, diverting 100 percent of the byproduct (2,000 tons a year) from local landfills. In addition, CP Kelco implemented additional waste management programs that focused on reusing, recycling or refurbishing its plastic, metal and fiber drums, wood pallets, and domestic appliance and electronic waste. Through these initiatives, CP Kelco increased its recycling/reuse rate to 79 percent.

