Future of Cleaning:
The Enzymatic Solution

3/22/2022

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Chemical Innovation?

Advanced Robotics?

What is the Future of Cleaning?

Novel Packaging
&
Dispensing Systems?

Machine Learning
&
AI Analytics?

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Future of Cleaning: Innovation Trends

Chemical Innovation

- Novel Chemical Technology
- Manufacturing Innovation
- Combinatorial Formulation

"Smart" Technology

- Utility Monitoring
  - Water Consumption
  - Energy Consumption
- Data Driven Product Dosing
- Hygiene Analytics and Reporting

Biome Control

- Home Biome Engineering

Robots!

Future of Cleaning: Innovation Trends

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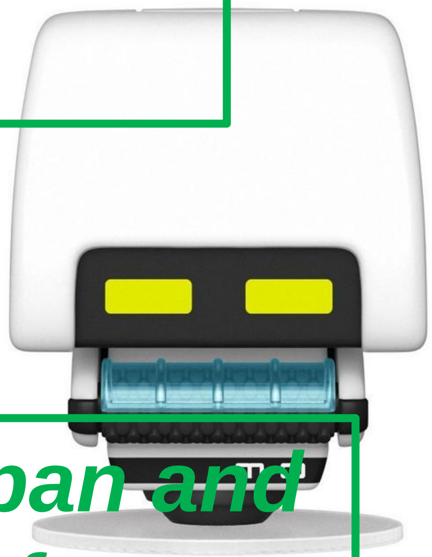

Enzymatic & Microbial Products Span and Enhance Multiple Innovation Platforms

Future of Cleaning: The Modern Consumer

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The information age has created an increasingly educated consumer

What do customers want most from their cleaning solutions?

- ✓ "Cleaner" Clean
- ✓ Safety
- ✓ "Green" Chemistry
- ✓ Eco-Friendly Packaging
- ✓ Multifunctional Cleaners
- ✓ Labeling Transparency
- ✓ Environmentally Responsible Manufacturing
- ✓ Ease of Use
- ✓ Cost Effective

Enabled via Enzymatic Solutions

Future of Cleaning: Green Confusion

The Green Spectrum

NPE's, STPP — *EDTA, LAE, Polyacrylates, SLS* — *Enzymes*

Phosphate

Synthetic Feed Stocks

Phosphorus

Readily Biodegradable

Phosphorus-Free

Inherently Biodegradable

Natural Feed Stocks

Vegetable-Based

Renewable Carbon

Enzymatic Cleaning

Microbial Cleaning

Future of Cleaning: Protease, Amylase & Lipase

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Proteases

- Among the first enzymes used in cleaning applications
- Basic ingredient in both laundry and dish products
- Cleaves proteins into smaller chains of amino acids
- Common protein stains:
  - ***Meat***
  - ***Grass***
  - ***Milk***
  - ***Blood***
  - ***Egg Yolk***
  - ***Sweat***

Amylases

- Starch stains can act as 'glue' for dirt particles in the air and wash water, making stains worse
- Cleaves large starch molecules into more manageable sugars
- Common starch stains:
  - ***Potatoes***
  - ***Pasta Dishes***
  - ***Baby Food***
  - ***Gravy***
  - ***Condiments***

Lipases

- Greasy stains are among the most challenging to remove, especially from synthetic fabrics
- Cuts lipids into smaller pieces which can be readily incorporated into surfactant micelles
- Common greasy stains:
  - ***Cooking Oils***
  - ***Fast Food***
  - ***Butter***
  - ***Cosmetics***

Future of Cleaning: Mannanase, Licheninase & Pectate Lyase

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Mannanases

- Galactomannans are widely used in food and industrial applications as stabilizers and thickeners
- Much like starch stains, invisible mannan stains can serve to provide a surface for additional soils
- Common mannan stains:
  - ***Guar gum***
  - ***Locust Bean Gum***
  - ***Processed Food***
  - ***Personal Care Products***

Licheninase

- Current dietary trends in high fiber foods as well as plant-based milk alternatives have created an increasing need for licheninases
- Cuts large hemicellulosic polysaccharides into more easily managed sugars
- Common fiber stains:
  - ***Oats***
  - ***Barley***
  - ***Quinoa***
  - ***Oat Milk***

Pectate Lyase

- Pectin stains arise from both natural and processed foods and is one of the reasons fruit and juice stains can be so hard to remove
- Cleaves pectin molecules into more soluble short chain sugars
- Common pectin stains:
  - ***Fruit Juices***
  - ***Smoothies***
  - ***Tomatoes***
  - ***Bananas***
  - ***Jams & Jellies***

Future of Cleaning: Cleaning & Care Cellulases

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Cleaning Cellulases

- Prevents redeposition of non-bleachable soils from dirt, clay and mud particles which can lead to fabric graying and color dullness over time
- Particulates can get trapped in short splintered textile fibers over time
- Function by removing ends of broken cellulose fibers that bind dirt
- Complimentary cleaning mechanism to common anti-redeposition agents

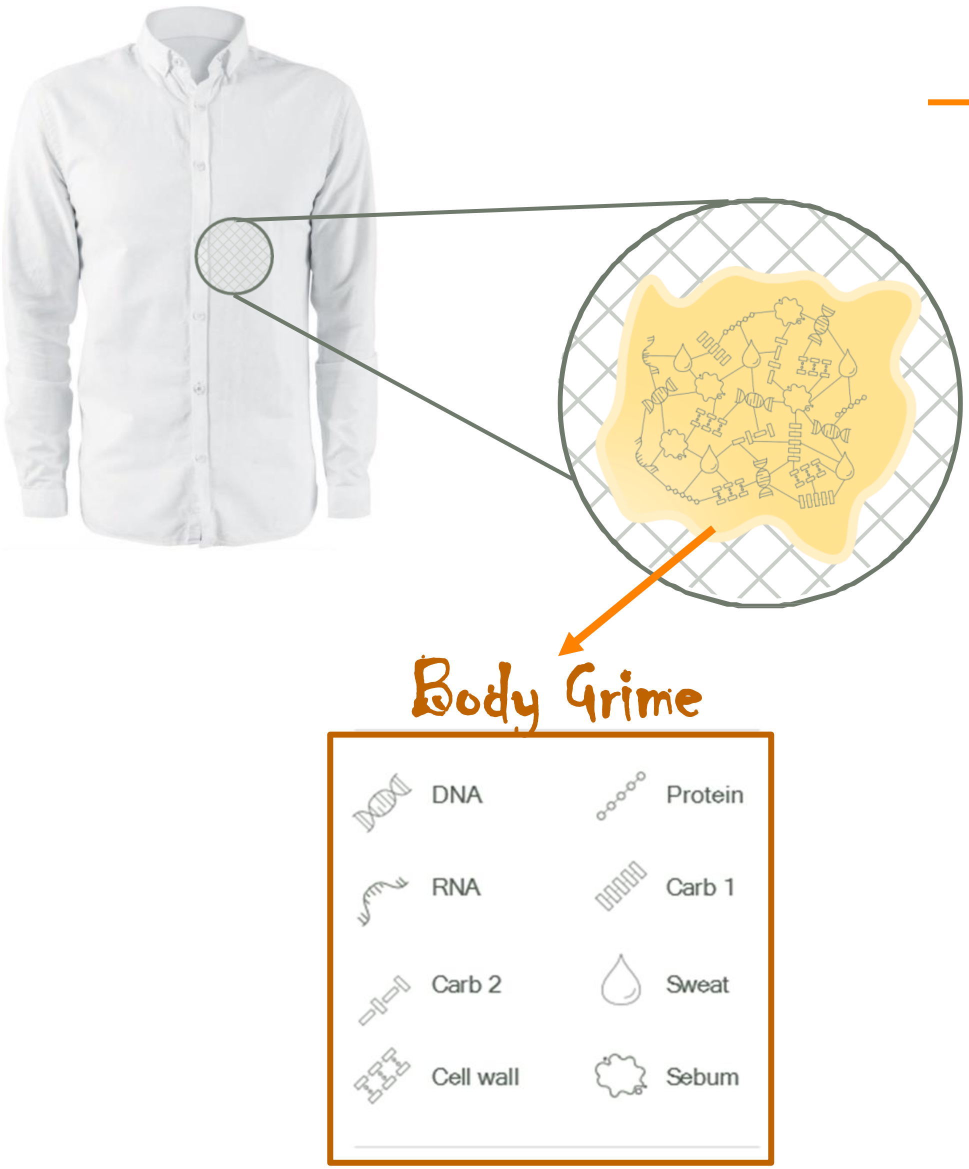
Care Cellulases

- Effectively removes fuzz and pill build-up on cotton fabric
- Provides both a maintenance and repair effect on the look of cotton
- Similar to cleaning cellulases, care cellulases modify the surface of the textile to restore color and/or whiteness
- Alternative technology to traditional optical brighteners

Future of Cleaning: Phosphodiesterase

Body Grime

- Invisible to the naked eye
- Builds up and trap dirt, bacteria and odors
- Fragrance masks, but does not remove odors
- Sanitizers and bleach kill bacteria, but remaining body grime will lead to the reoccurrence of washed clothes not feeling clean and fresh



Phosphodiesterases

- New class of enzymes currently entering the market, also referred to as a nuclease
- Target substrate is extracellular DNA, also called ‘Body Grime’
- Cleaves the phosphodiester bond found in eDNA
- Body grime acts as a glue for dirt and malodors

Future of Cleaning: Multi-enzyme Solutions

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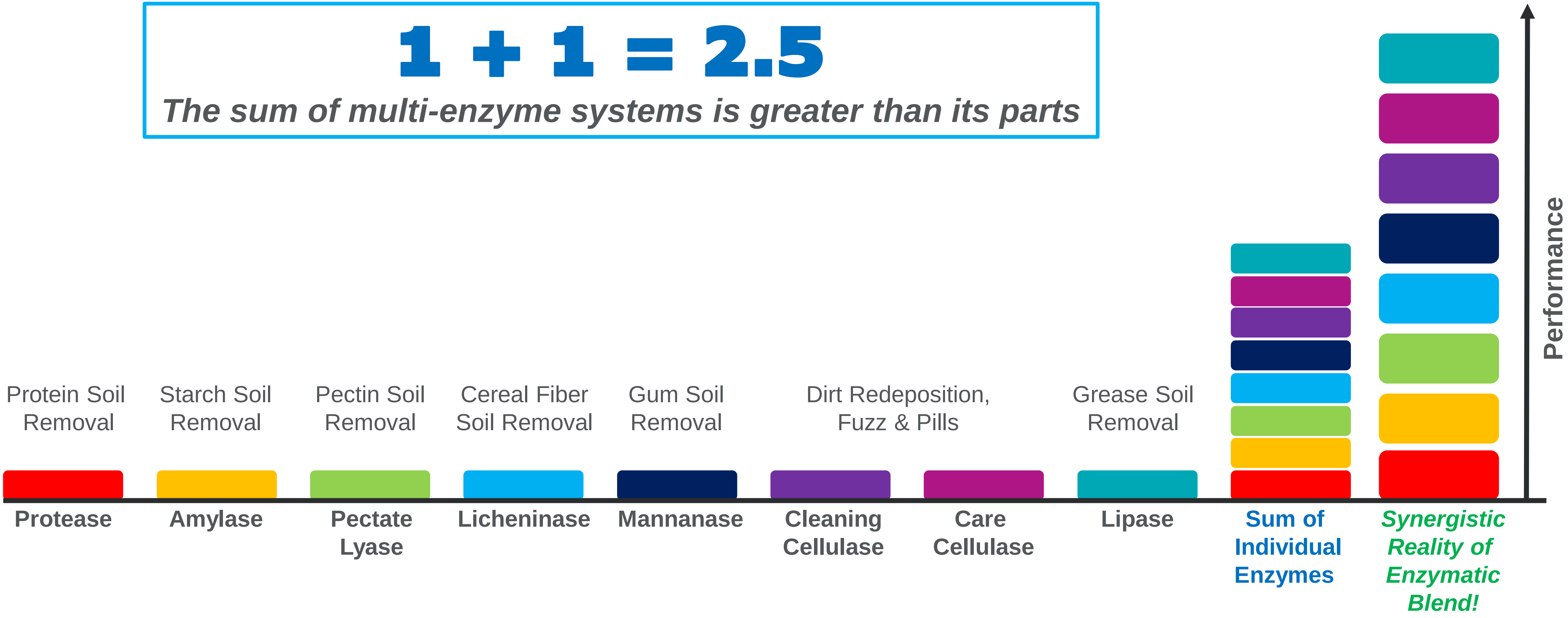
1 + 1 = 2.5

The sum of multi-enzyme systems is greater than its parts



Future of Cleaning: Formulating Liquid Enzymatic Products

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Polyols

- Conventional approach is to use 2-5% polyol; e.g. propylene glycol and/or glycerol
- Particularly important when using boric acid protease stabilization
- Newer enzymes are more robust and may not require the addition of polyols

Calcium

- Use 0.02 – 0.06% $CaCl_2$ for optimal protease and amylase stability
- Newer enzyme variants do not require added salts

pH

- Preferably near biological pH, i.e. 6.5 – 8.5

Future of Cleaning: Formulating Liquid Enzymatic Products

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Order of Addition

- Add $CaCl_2$ and sodium formate during the heating step
- Addition of enzymes should occur at the end of the batching process when the temperature is reduced
- If making a multi-enzyme system, add each enzyme individually
- Do not pre-blend enzymes prior to adding to the batch
- Alternatively, use pre-stabilized and blended enzyme solutions from the manufacturer

Surfactants

- Conventional approach is to use mixed surfactant systems keeping the anionic-to-nonionic ratio at 1:1 or preferably 1:2.
- LAS can challenge enzymatic stability, so combining with SLES can mitigate this issue
- Newer enzyme classes are more robust and less sensitive to surfactant chemistry

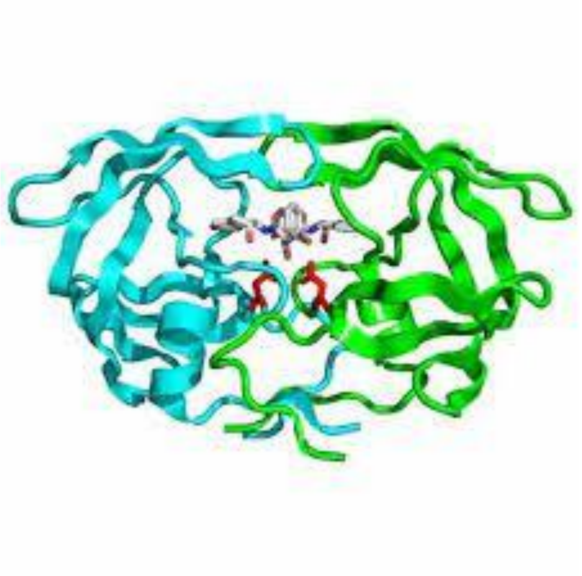
Other Considerations

- Strong chelators should be used with caution, but newer enzymes are progressively more tolerant to chelants
- Avoid bleach and formaldehyde-releasing preservatives. CMIT/MIT, BIT and 2-Phenoxyethanol are all fine
- Use caution when blending with oxidizing and reducing agents
- Most minor ingredient, i.e. fragrance and dyes, are not a concern

Future of Cleaning: Enzymes Versus Microbes

Enzymes

- Produced by all living organisms
- Not alive
- Complex proteins
- Do a single, highly specific reaction, repeatedly
- Initiate bond cleavage thousands of times per second



Microbes

- Living organisms
- Take time to awaken and show activity
- Multiply and clean based on nutrient availability
- Contain >2 million proteins
- Biological nanotech, i.e. 'Enzyme Factories'

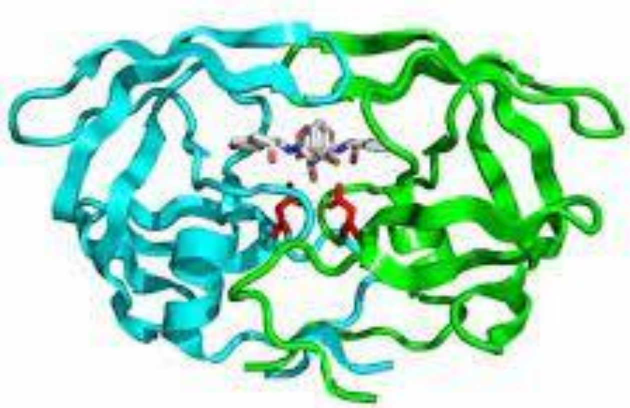
Future of Cleaning: The Probiotic Cleaning Model

Chemistry

Immediate removal and encapsulation of soils

Enzymes

Quick degradation of specific targeted organic soils



Microorganisms

Continuous degradation of organic soils including protein, starch, fat, volatile fatty acids, etc.

Time

0 — **1 Min** — **1 Hour** — **Multiple Days**

Future of Cleaning: Formulating With Microbes

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Surfactant Considerations:

Anionic Surfactants

- Can contain preservatives as part of the manufacturing process – potential impact on germination
- Generally compatible
- Avoid alkylbenzne sulfonate, alkyl sulfonates and alky sulfates
- Recommendation: SLES

Nonionic Surfactants

- Generally compatible and recommended
- Recommendation: Alkyl polyglucosides (APGs) and alcohol ethoxylates

Amphoteric Surfactants

- Generally compatible – can be pH dependent
- Avoid cocamidopropyl betaine due to the presence of a quaternary ammonium cation

Cationic Surfactants

- Avoid – May impact spore viability and/or cause spore clumping

Future of Cleaning: Formulating With Microbes

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pH Range & Considerations:
Cytoplasmic pH homeostasis has been studied extensively in *B. subtilis*, (model organism for Bacillus species) which maintains cytoplasmic pH within approximately pH 7.3 to pH 7.6 during vegetative growth over a range of environmental pH, from pH 6.0 to pH 9.0

Chelant Considerations:
Compatible chelators include the following:

- Sodium citrate
- Methylglycinediacetic acid (MGDA)
- Tetrasodium salt of N,N-Dicarboxymethyl glutamic acid (GLDA)
- Tetrasodium salt of iminodisuccinic acid

Preservative Considerations:
Recommended: 2-phenoxyethanol (*note* Not a registered preservative in all countries)
Possible: pH Sensitive preservatives, i.e. sorbates and benzoates (Kalaguard SB). Greatest efficacy at pH <6
Not Recommended: Chlorine, peroxide, peracids, glutaraldehyde, formaldehyde release agents
note Isothiazolinones have been used, but may inhibit cleaning. Can be used in dilutable products, but will require testing.

Future of Cleaning: Formulating With Microbes

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Enzyme Boost Considerations:

Enzymes may be included with the spore package, but spore stability would need to be closely monitored during product development due to possible interactions between the spores and the enzyme stabilizer package.

Fragrance Considerations:

Generally compatible, but many natural fragrances, i.e. essential oils, can have an inhibitory or ‘kill’ effect on the spores.

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