LIBERTY UNIVERSITY

Exploding Banana Puree

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Background

Discovery: novel spray process for thick slurries called Wave-Augmented Varicose Explosions (WAVE)

Importance: this represents new "wave-augmented" atomization technology, where waves enhance the breakup of viscous, non-Newtonian fluids (which are difficult to atomize)

Applications:
- Manure slurry atomization for energy conversion + fertilizer
- Gelled propellant atomization for aerospace

Defining Terms:
- *Non-Newtonian fluid:* viscosity varies with shear force applied. Example: ketchup, which begins to flow more easily when it is being squeezed from a bottle.
- *Atomization:* breakup of a bulk continuous fluid into smaller droplets in a spray

Introduction

Objective: elucidate mechanisms driving disintegration of banana puree in novel WAVE spray nozzle

Significance: this is the *first ever* study of WAVE atomization, which is a revolutionary new spray process for viscous, non-Newtonian liquids (i.e., thick slurries like banana puree)

Pulsing Nature of System:
- Highly periodic wave formation creates a pulsing spray at 1000 Hz frequency (periodic explosions of liquid)

Why Banana Puree?
- Highly viscous
- Non-Newtonian
- Fun!

Computational Study:
- Banana puree is used as a surrogate to represent a general class of viscous, non-Newtonian fluids
- Computer simulations model spray dynamics

Methods

Spray Nozzle Design:
- Annular puree flow is injected into a central high-velocity steam flow just before nozzle exit
- Low GLR of 2.7% (lower is better → more efficient)

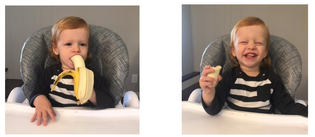
Modeling Banana Puree Viscosity:
- Described by Herschel–Bulkley model
- Shear-thinning beyond certain yield shear stress
- Viscosity lowers with increased temperature

CFD Model:
- 132 million cell mesh (more cells → better resolution)
- 2000 computing processors (more processors → faster)
- 3 of months running model
- This would take 125 years to compute on your laptop!

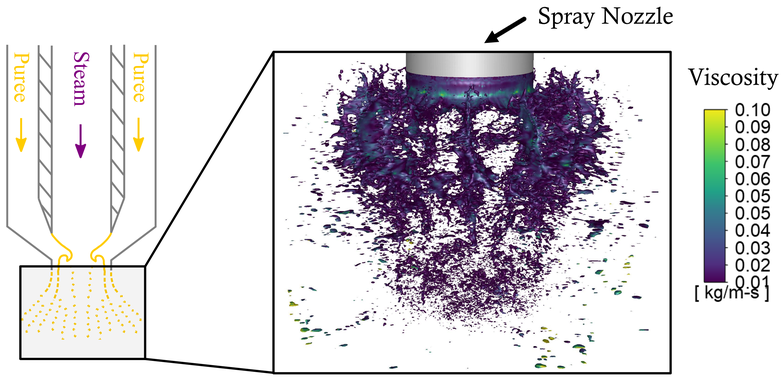
CFD = Computational Fluid Dynamics
GLR = Gas-Liquid Ratio (ratio of mass flow rates)

We present a **new way** to effectively **spray thick slurries** (like banana puree): Wave-Augmented Varicose Explosions (WAVE)

Photos by Daniel Wilson



1. Eat 2. Treat! 3. Play 4. Puree



Banana Puree Production [1] → Wave-Inducing Nozzle Design → Waves Cause Pulsing Spray (Explosions of Puree)

Unique waves inside the spray nozzle **provide mechanisms** to break up banana puree into **small droplets**

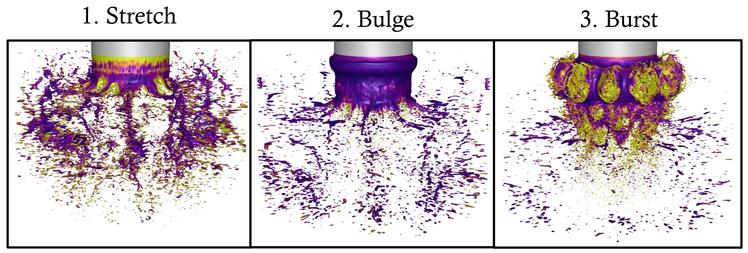


Figure 1. *Pulsing sequence with puree surface colored by strain rate.*

View Animations:

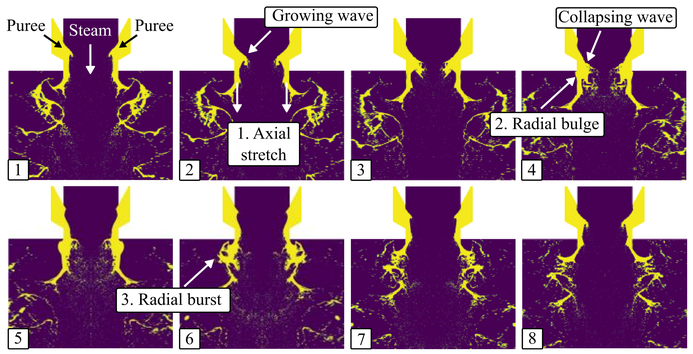


Figure 2. *Sequential side views of banana puree (yellow) through one pulsing sequence [1].*

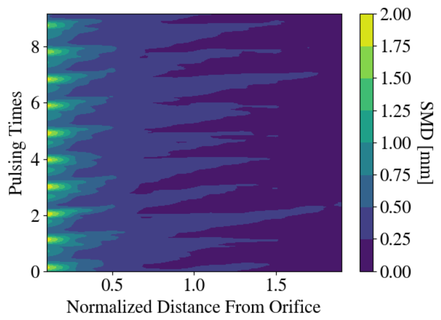


Figure 3. *Contours showing spatiotemporally fluctuating droplet sizes [1].*

Results and Conclusions

Pulsing Pattern:
1. Stretch
   - Annular puree sheet stretches down while wave forms
2. Bulge
   - Puree bulges around nozzle exit as wave collapses
3. Burst
   - Puree bursts radially in a violent explosion

Atomization Mechanisms:
1. Wave Impact Momentum
   - Wave crashes into puree sheet
   - Radial momentum flux rate = 1.7×10^5 kg/m s^2
   - Traps steam bubbles (effervescence)
2. Pressure Buildup
   - Intense steam compression windward
   - Large pressure gradient across puree sheet
3. Droplet Breakaway
   - Increased area for steam to strip droplets
   - Thinning, fingering at wave crest
   - Steam penetrates wave (more effervescence)

Droplet Production:
- Droplet sizes fluctuate spatiotemporally in a wave pattern

Christian Worldview

1. **Intelligibility** → God created an intelligible universe that can be studied
2. **Rationality** → God gave us the capacity to know Him and understand the world around us
3. **Creativity** → God designed us to create by re-ordering that which is around us for new and useful purposes
4. **Design** → bananas are a wonderfully designed fruit

Future Work

Evaluate dependence of WAVE atomization on…
1. Steam velocity: lower steam velocity → less steam usage → more efficient atomization
2. Non-Newtonian fluid: compare response of Newtonian fluid in spray nozzle to the present study
3. Geometry: alter geometry → wave physics change → nozzle design optimization

References

1. D. M. Wilson and W. Strasser, "A Spray of Puree: Wave-Augmented Transonic Airblast Non-Newtonian Atomization," Physics of Fluids 34 (7), (2022).
2. D. M. Wilson and W. Strasser, "The Rise and Fall of Banana Puree: Non-Newtonian Annular Wave Cycle in Transonic Self-Pulsating Flow," Physics of Fluids 34 (7), (2022).
3. Strasser, W., Battaglia, F., "The Effects of Prefilming Length and Feed Rate on Compressible Flow in a Self-Pulsating Injector," *Atomization and Sprays*, 27(11), pp. 929-947, (2017).
4. Strasser, W., "Towards Atomization for Green Energy: Viscous Slurry Core Disruption By Feed Inversion," *Atomization and Sprays*, (2020).