Chocolate Processing

PURDUE UNIVERSITY

Agricultural & Biological ENGINEERING

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Objective:

To design a chocolate production facility utilizing low energy and low waste concepts while maintaining the quality of the product.

Market Analysis:

- •The United States consumes 34 pounds of chocolate per capita.
- •75% of the cocoa crop is grown in West Africa.
- • 40% of the world's cocoa comes from the Ivory Coast alone.
- •Trends show the demand for cocoa is increasing but the economic incentives for farmers are decreasing.
- •The proposed production facility will have the capacity to supply a population roughly the size of Indianapolis; this equates to approximately 8 million pounds per year.

Science of Chocolate Quality:

- •Desirable chocolate is often characterized by a melting temperature near body temperature (37 C).
- •The flavor profile of the cocoa beans is determined by roasting procedure.
- •A smooth texture is achieved by ideal particle size and optimal fat crystallization.
- •The cooling rate of the chocolate affects the crystalline structure of the fat in the product. These fat crystalline forms are known as polymorphs and they exhibit various melting temperatures. This affects the final melting temperature and texture of the product.

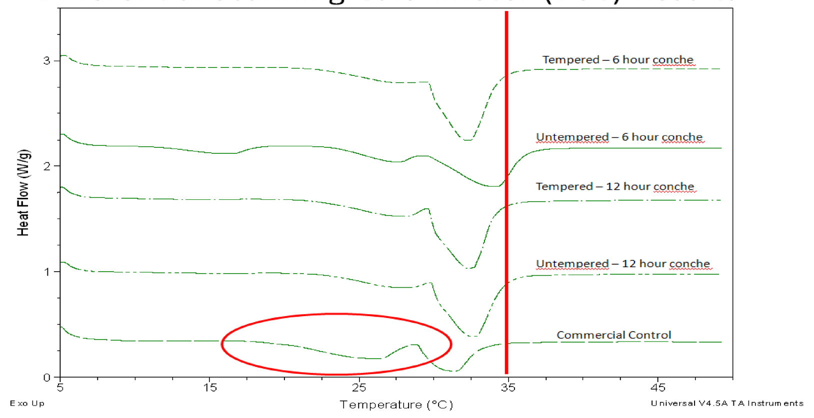
Experiment:

- •Tested two variables to determine the effect of each variable on the quality of the final product.
- •Melting temperature profiles determined using a DSC.
- •Mouth-feel quantified using a viscometer at body temperature.

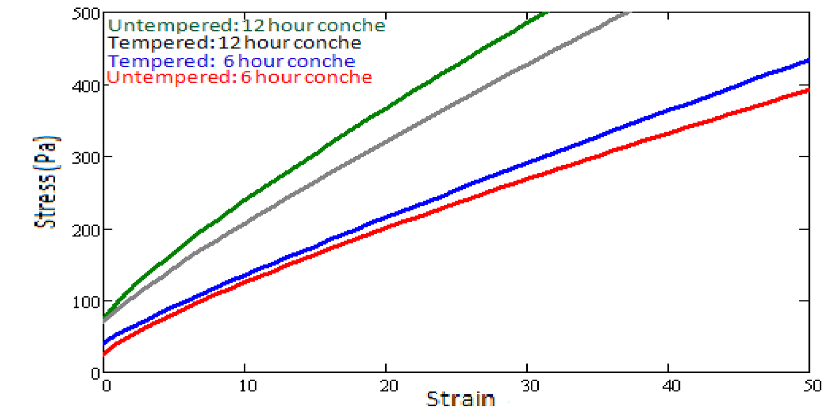
Experiment Number	Conching Time	Treatment
1	6 hours	Tempered
2	6 hours	Untempered
3	12 Hours	Tempered
4	12 Hours	Untempered

Experimental Results:

Differential Scanning Calorimeter (DSC) Results

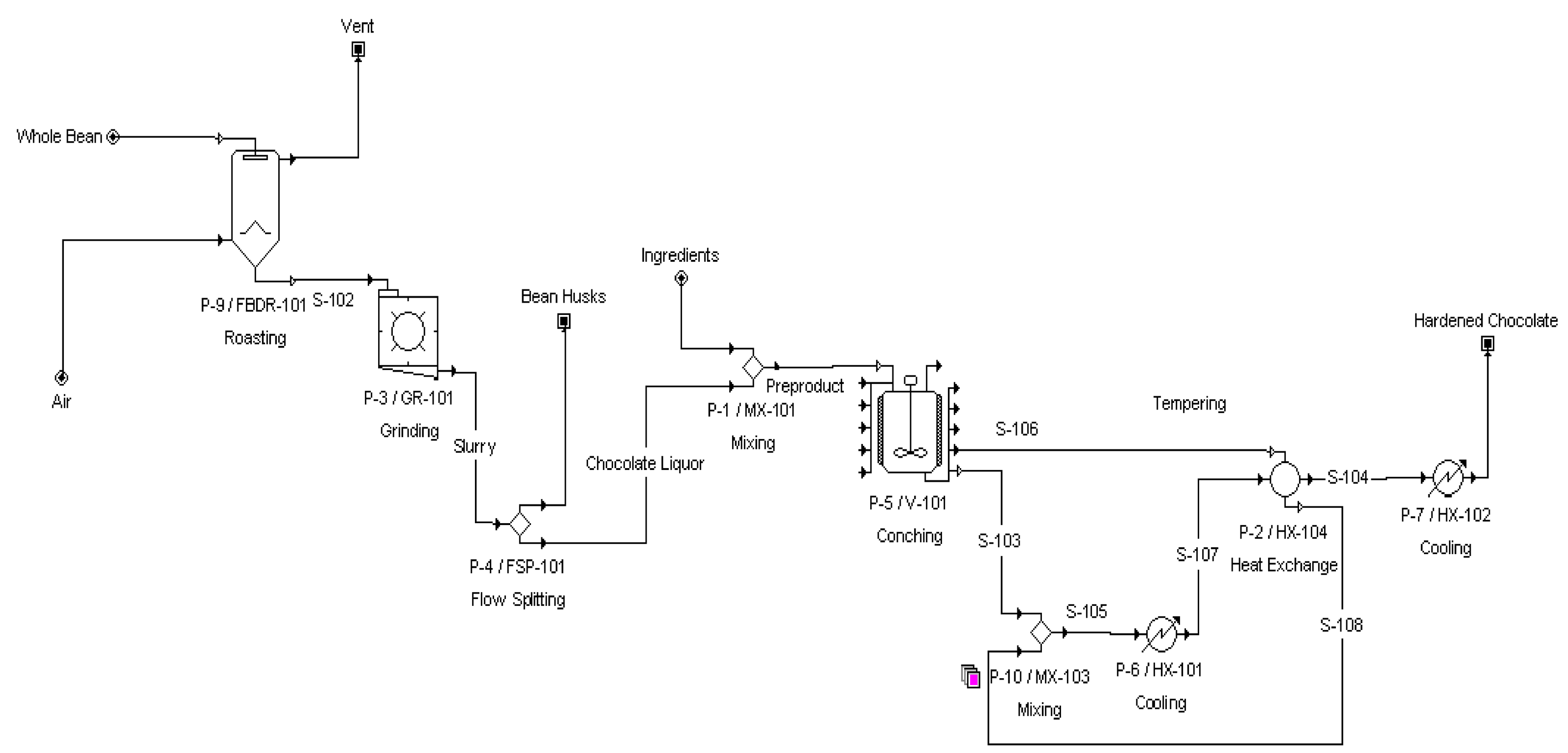


Herschel-Bulkley Rheological Model



- •DSC Results:
  - •The control shows a melting temperature near body temperature.
  - •The variables show a melting temperature lower than body temperature.
  - •The tempered melting profile is more characteristic of a homogenous product than the untempered sample.
- •Viscometer Results:
  - •The curves show chocolate exhibits pseudoplastic rheological behavior.
  - •The rheological data shows that the chocolate samples exhibit a yield stress (Bingham plastic).
  - •The chocolate that was conched for 12 hours exhibits a lower yield stress than the 6 hour sample.

Process:



- •**Roasting**: Eliminates microbes, dries, develops flavor
  - •152 C for a residence time of 20 minutes
- •**Cracking/Winnowing**: Separates husk from nib
- •**Grinding**: Liquefies beans into cocoa liquor
- •**Conching**: Blends ingredients; polishes sugar particles and distributes fat globules
  - •Residence time of 12 hours
- •**Tempering**: Controls cooling rate to crystallize fat to its most stable polymorph
  - •Cool to 29^{o}C heat to 38^{o}C cool to room temperature

Plant Design:

- •Waste reduction: Husks not wasted
  - •Production of high quality mulch
  - •Tea and beer flavorings
  - •Compost
- •Energy recovery
  - •Heat exchange in tempering
  - •Heat exchange between conching and roasting processes
- •Continuous process
  - •Rows of longitudinal conching machines
  - •Conveyer style roasting

Economic Analysis:

COST OF PRODUCTION	
Raw Material	**Annual Cost**
Beans	4891291.72
Cocoa Butter	2786179.28
Nonfat Dry Milk	4540440.30
Sugar	1641688.13
Other Costs	
Energy	607893.66
Air	2860.48
Water	369839.50
TOTAL COST	14840193.06

SALES REVENUE	
Chocolate Sales	115574844.00
Husk sales	45862.96
TOTAL REVENUE	57810353.48

Global Impact:

The savings that result from a more energy efficient design will contribute to the bottom line profit of the plant. These savings will make it more economically feasible to pursue a fair trade product at a reasonable cost per unit. Participation in fair trade can provide greater economic incentives for cocoa farmers. It will also promote workplace standards and prevent the use of child labor on cocoa plantations.

Acknowledgements:
Dr. Martin Okos
Dr. Osvaldo Campanella
Dr. Bhavesh Patel

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