Thermogravimetric Analysis of the Frying Process for Protein-based Foods

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INTRODUCTION

Increasing the efficiency of meat system processing will decrease raw material waste and will reduce overall energy consumption. Not only will this help meat processors reduce their imprint and utilize as much of the animal as possible but will also create larger profit margins for meat processors.

AIM

Increase the efficiency of the protein-based food product manufacturing process

OBJECTIVES

1. Applied mass and energy balances during frying of protein-based food product
2. Determine the effect of input product temperature and batch size on output variables (Aw, fat content, MC)
3. Determine the influence of composition of raw product and water activity, moisture content, and color of finished product
4. Evaluate image processing as a potential method for characterizing final product using colorimeter and thresholding values

PLAN

Effect of batch size experiment: **Completed**	Batch sizes: 150g, 250g, 350g, 400g
Effect of input product temperature experiment: **Completed**	Input product temp: -2 °C, 10 °C, 20 °C
Effect of fry time experiment: **Completed**	Fry times: 4 mins, 6 mins, 8 mins
Effect of composition experiment: **Ongoing**	High fat, mixed

Figure 1. Experimental Design schematic.

Mathematical equations for a comprehensive mass and energy balance have been developed to understand where process efficiency can be increased.

The bench-scale system can mimic large-scale meat processing systems and control key pork belly frying parameters.

METHODS

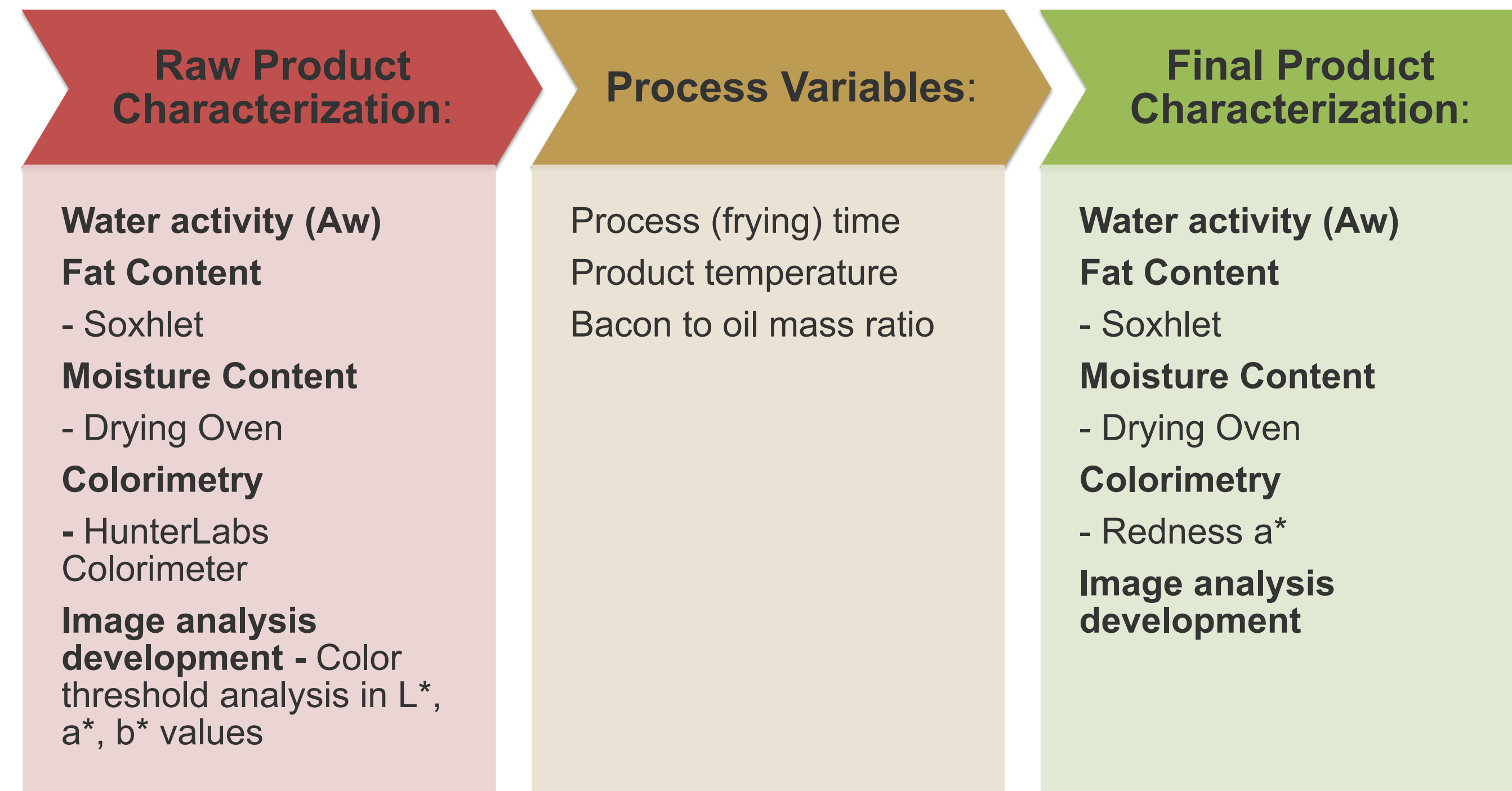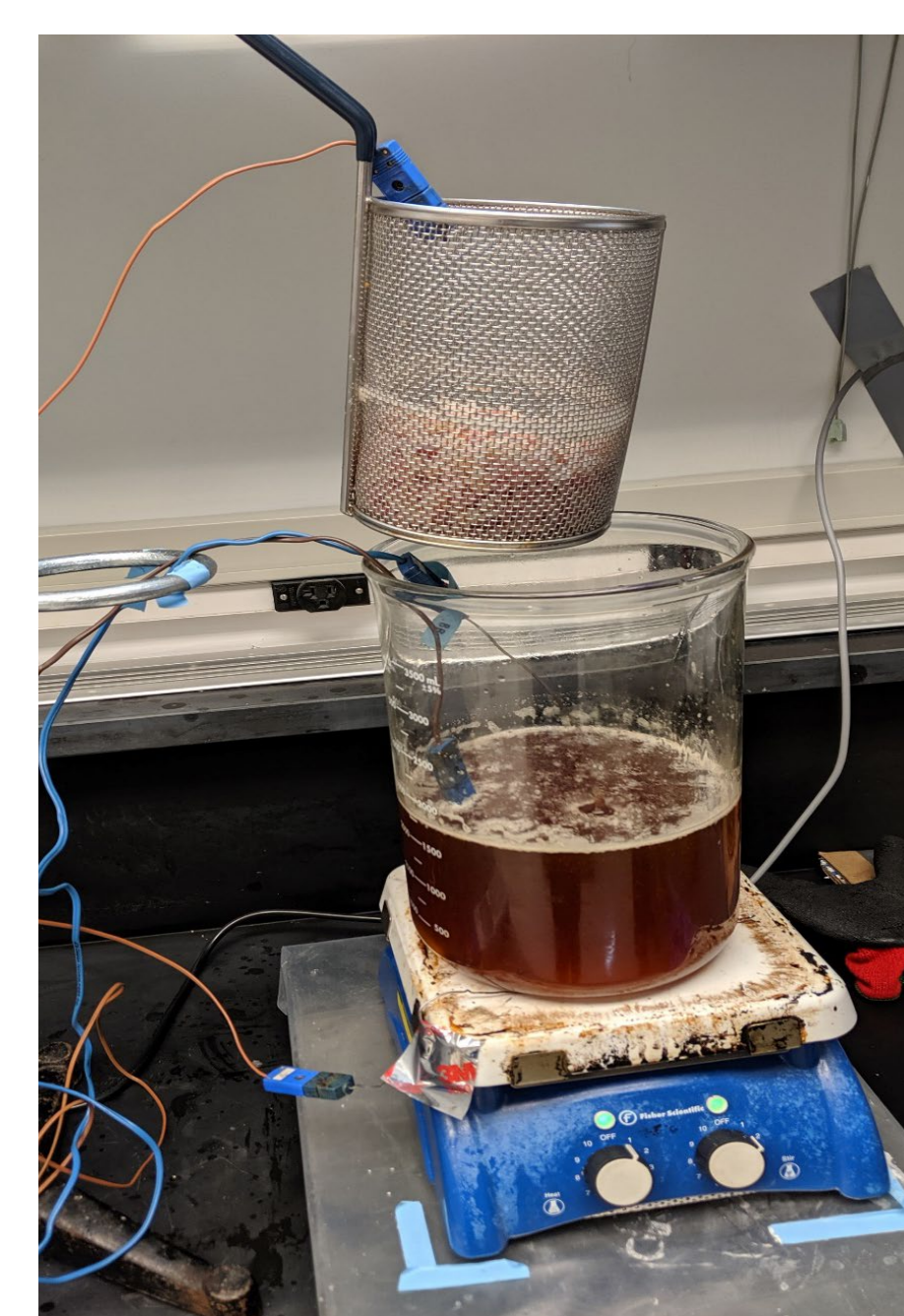| Raw Product Characterization:	Process Variables:	Final Product Characterization:
Water activity (Aw)	Process (frying) time	Water activity (Aw)
Fat Content	Product temperature	**Fat Content**
- Soxhlet	Bacon to oil mass ratio	- Soxhlet
Moisture Content		**Moisture Content**
- Drying Oven		- Drying Oven
Colorimetry		**Colorimetry**
- HunterLabs Colorimeter		- Redness a*
Image analysis development - Color threshold analysis in L*, a*, b* values		**Image analysis development**

Figure 2 and 3. Experimental set up of bench top frying process on left. Raw and cooked product characteristics are analyzed to develop a process model on right.

RESULTS

Change in Average Water Activity (Aw) with Input Product Temperature at Different Fry Times

Change in Average Moisture Content with Input Product Temperature at Different Fry Times

Fry Time = 4 mins
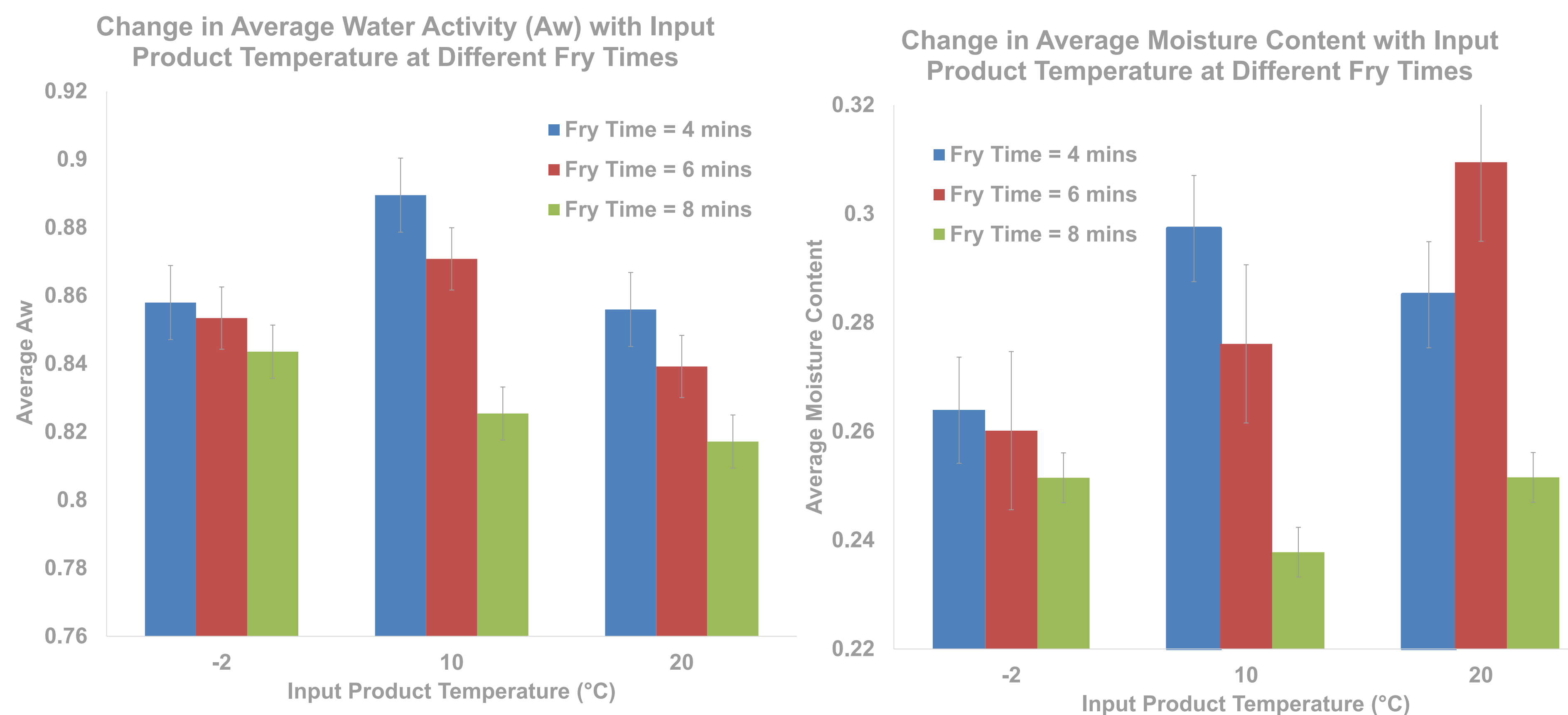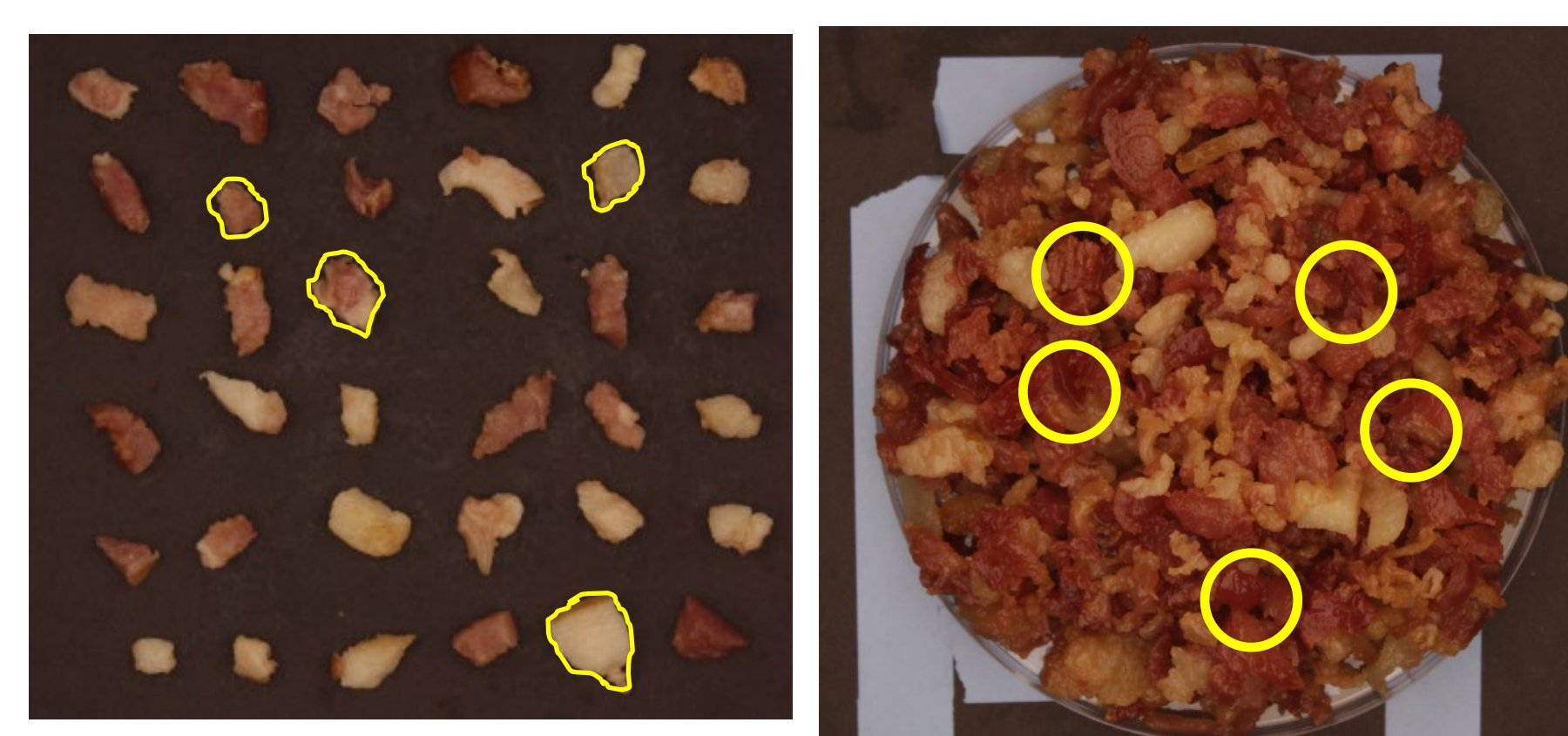Fry Time = 6 mins
Fry Time = 8 mins

Figure 4 and 5. Effects of input product temperature (-2°C, 10°C, 20°C) on moisture content (MC%) and water activity (Aw) for fry times of 4, 6, and 8 minutes with batch size of 400g bacon bits to 2000g oil.
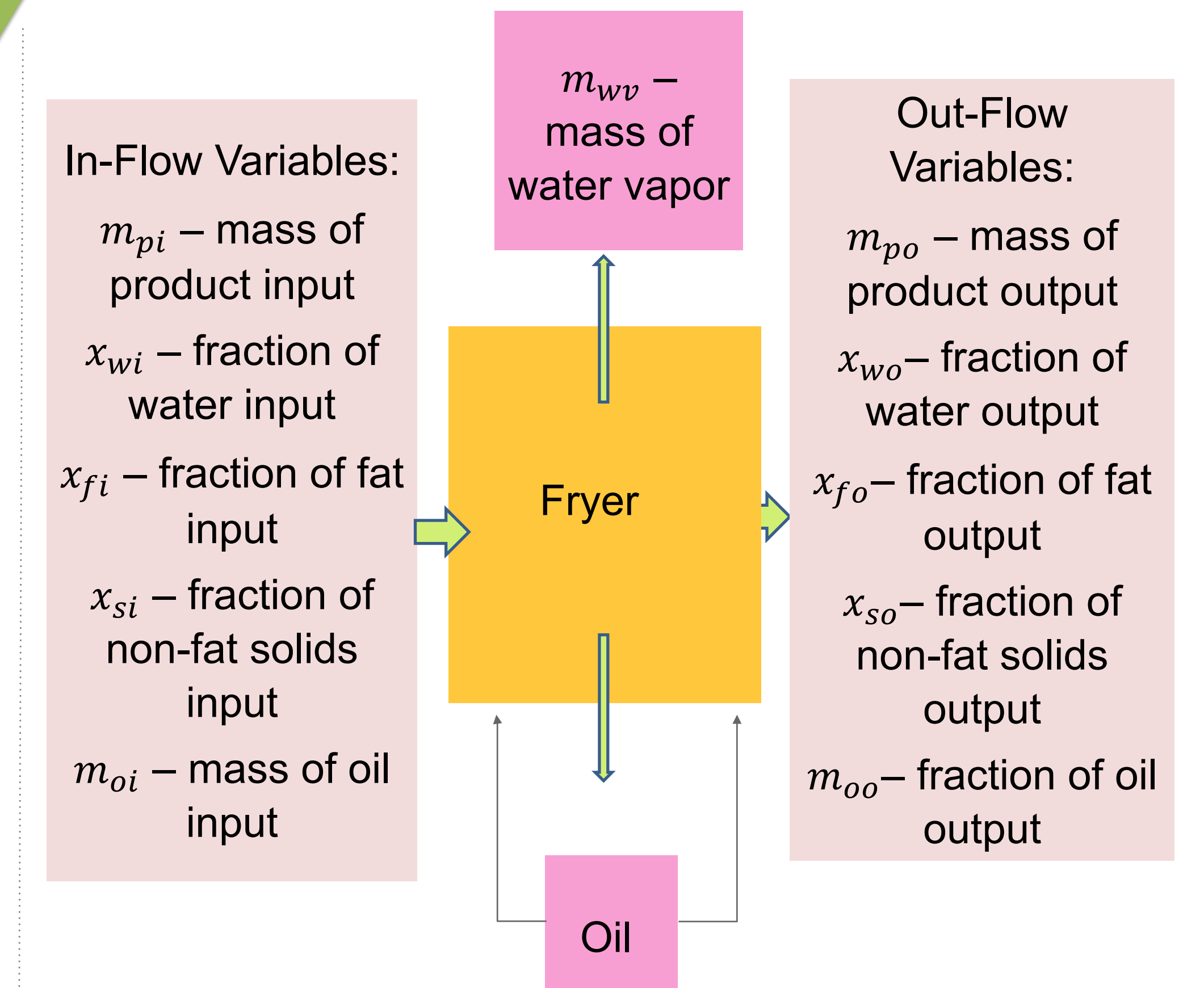
IMAGE ANALYSIS

- Regions of interest are selected to output an average L, a*, b* (color) value for each bit and overall fry time picture.
- Bits placed in petri dish are experimental representatives of the bacon bits coming off the frying line.
- Can be used with foreign detection imaging to ensure quality of product on processing line.

Figures 6 and 7. Examples of Image analysis pictures to develop color scale. The highlighted regions of interest on the left picture are representative of bacon bits thresholded at a* value level of 15.50-17.50 (medium light) and ROIs on the right are representative of bits thresholded at a* value level of 13.50-15.50 (medium dark)

Figure 8. Input and output components of the mass and thermal energy balance analysis.

In-Flow Variables:

m_{pi} – mass of product input

x_{wi} – fraction of water input

x_{fi} – fraction of fat input

x_{si} – fraction of non-fat solids input

m_{oi} – mass of oil input

m_{wv} – mass of water vapor

Fryer

Oil

Out-Flow Variables:

m_{po} – mass of product output

x_{wo} – fraction of water output

x_{fo} – fraction of fat output

x_{so} – fraction of non-fat solids output

m_{oo} – fraction of oil output

Mass Balance: $m_{pi} + m_{oi} = m_{po} + m_{wv} + m_{oo} + m_R$

Component 1 – Water: $m_{pi}x_{wi} = m_{po}x_{wo} + m_{wv}$

Component 2 – Oil (includes fat): $m_{pi}x_{fi} + m_{oi} = m_{po}x_{fo} + m_{oo}$

Component 3 - Nonfat Solids: $m_{pi}x_{si} = m_{po}x_{so} + m_R$

CONCLUSIONS

- Preliminary effect of batch size data indicates MC and Aw are lower at higher batch sizes
- Preliminary effect of input product temperature data indicates that higher input product temperature has consistently lower Aw values
- The mass and energy balance model provides predictions of various processing parameters for evaluation of meat industry manufacturing.
- By customizing the bacon bit frying unit based on the quality attribute models generated can provide a system scale-up parameters for both research and industry.

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