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| **Take home assignment (Individual): Building the model (Due beginning of class 9/27)** | | |
| **Please outline and describe how your model works in terms of computational structures. For each structure, please explain why the programming technique or process used was chosen. Include as much detail as possible, doing this for each computational structure within your model (groups of variables, loops, conditional statements, sets of equations etc).** | | |
| Computational Structure:  Clear the console in lines 19-21  Define thermal and physical properties and convert to correct units lines 28 – 96   * Filling properties lines 28-30 * Steam immersion retort properties lines 33-35 * Cooling water immersion properties lines 38 – 45 * Production line properties lines 48 – 52 * Kinetic properties of food components lines 56 – 67 * Kinetic properties of microorganisms lines 70 – 79 * Nutrient content of food materials lines 85 – 96   Calculating parameters to determine the number of layers required to analyze for heat transfer process lines 103 – 110  Calculating initial parameters for heat transfer process lines 112 – 117  Setting up empty arrays and initial points for plotting later lines 122 – 140  While loop to iteratively calculate the temperature and reduction of each microorganism and nutrient of the can at each node over time until the minimum reduction has been reached lines 142 – 191   * Move the time step line 143 * Calculate the temperature and reduction of the microorganism and nutrient at the center node lines 145 – 159 * Calculate the temperature and reduction of the nutrients on the surface lines 159 – 166 * Calculate the temperature and reduction of the nutrients between the surface and the center lines 167 – 173 * Move the node value line 175 * Reset the parameters for the next loop, find the average nutrient content of the can at the time, and store data points for plotting lines 177 – 184 * Integrate the reduction of the nutrients and microorganisms lines 185 – 190   Print statements to inform of the time to reach minimum sterile requirements and the maximum temperature required to do so lines 193 – 195  While loop to iteratively calculate the temperature and reduction of each microorganism and nutrient of the can at each node over time until the desired average temperature has been reached lines 197 – 246   * Move the time step line 198 * Calculate the temperature and reduction of the microorganism and nutrient at the center node lines 200 - 213 * Calculate the temperature and reduction of the nutrients on the surface lines 214 – 221 * Calculate the temperature and reduction of the nutrients between the surface and the center lines 222 – 229 * Move the node value line 230 * Reset the parameters for the next loop, find the average nutrient content of the can at the time, and store data points for plotting lines 232 – 239 * Integrate the reduction of the nutrients and microorganisms lines 240 – 245   Print statements to inform of the total time to sterilize and cool and total reduction of each microorganism and nutrient lines 248 – 255  Find the average log reduction of each nutrient over time lines 257 – 259  Plot figures lines 266 – 293   * Temperature profile of the center lines 266 – 271 * Reduction of microorganisms lines 273 – 282 * Reduction of nutrients lines 284 – 293   User-defined functions lines 295 – 452   * Convert Fahrenheit to Celsius lines 295 – 303 * Convert inches to centimeters lines 305 – 312 * Convert kilocalories to joules lines 314 – 321 * Convert days to minutes lines 323 – 330 * Calculate density of food with Choi-Okos equation lines 332 – 348 * Calculate heat capacity of food with Choi-Okos equation lines 350 – 367 * Calculate thermal conductivity of food with Choi-Okos equation lines 369 – 385 * Calculate thermal diffusivity of food with Choi-Okos equation lines 387 – 403 * Calculate M lines 405 – 414 * Calculate the temperature of the center lines 416 – 422 * Calculate the temperature of the surface lines 424 – 430 * Calculate the temperature in the rest of the nodes lines 432 – 440 * Calculate the thermal reduction of microorganisms and nutrients lines 442 – 452 | How does it work? Why was it programmed this way?  This allows the code to function smoothly without mistakenly “remembering” past values and clears the console of clutter from past errors.  Define how heat moves through the material so that the equations later in the code can be used. Most of the variables came from the memo/assignment document but the food composition data came from the USDA database. User-defined functions (described below) converted Imperial units to SI units for easier calculations.  This works by assuming a small delta t value (1 second) and an M value of 4 and then calculating delta x from these values before dividing the radius of the can by the number of layers. This must be done to set the number of iterations the program must run through for each time iteration.  This uses the Choi-Okos equation for the given initial temperature in order to start the process of calculating the heat transfer behavior.  The arrays are a helpful way to store information to be used later for each iteration when an unknown number of iterations will occur as before the loop it is unknown how much time it will take to reach the minimum desired sterilization level.  This loop first steps the time and then goes through each node from the surface to the center and calculates the temperature at that node by first calculating all the parameters needed via the Choi-Okos using the last temperature at that node. Then a new temperature is calculated with the equations defined in Geankoplis. The desired temperatures are stored in an array. The k value for each microorganism and nutrient is then calculated. At the end of the loop, the desired data points are saved, the average nutrient content is found for that time point and saved, and the total reduction in each microorganism and nutrient is calculated with the trapezoidal method. Then, the parameters such as time and node number are reset for the next iteration. This continues until the targeted microorganism, *C. Botulinum*, reaches the minimum required reduction to meet sterilization requirements.  This loop first steps the time and then goes through each node from the surface to the center and calculates the temperature at that node by first calculating all the parameters needed via the Choi-Okos using the last temperature at that node. Then a new temperature is calculated with the equations defined in Geankoplis. The desired temperatures are stored in an array. The k value for each microorganism and nutrient is then calculated. At the end of the loop, the desired data points are saved, the average nutrient content is found for that time point and saved, and the total reduction in each microorganism and nutrient is calculated with the trapezoidal method. The average temperature of the can is calculated. Then, the parameters such as time and node number are reset for the next iteration. This continues until the average temperature of the can reaches the desired temperature.  These inform the user that the code is progressing as it should and outputs important data points such as the reduction of the microorganisms and nutrients and the total sterilization and cooling time.  This section is performed to be able to plot the average nutrient activity of the can.  The plots are a visual way to see what occurs during the sterilization and cooling processes with regards to the temperature and microorganism and nutrient content.  These functions convert imperial units to SI units.  These functions convert imperial units to SI units.  These functions convert imperial units to SI units.  This function converts the time to consistent units.  These functions use the food composition properties and the Choi-Okos equations to calculate the thermal properties of the food as temperature changes.  These functions use the food composition properties and the Choi-Okos equations to calculate the thermal properties of the food as temperature changes.  These functions use the food composition properties and the Choi-Okos equations to calculate the thermal properties of the food as temperature changes.  These functions use the food composition properties and the Choi-Okos equations to calculate the thermal properties of the food as temperature changes.  This function iterates M and ensures that as alpha changes, M does not go below 4 as that would affect the heating and cooling behavior.  These functions calculate the temperature at different nodes using formulas from Geankoplis.  These functions calculate the temperature at different nodes using formulas from Geankoplis.  These functions calculate the temperature at different nodes using formulas from Geankoplis.  This function calculates the reduction in different organisms and nutrients using formulas from Geankoplis. | |
| **Please describe any assumptions made during the modeling process and why those may have been good or appropriate assumptions?** | | |
| Assumption(s):   * No external gradient in temperature * The can is a closed system: no mass or light enters or exits the can * The metal can’s heat transfer resistance is negligible (the can temperature is the same as the environmental temperature). * The can is filled completely with food material. * Ambient pressure is constant. * Heat only enters the can radially | Why did you make this assumption?   * We are only interested in what occurs in the can * Mass movement is undesirable; light energy will not be added * The can material has high thermal conductivity. * Air is not desirable in the can * This would cause a change in temperature   The dominant face for heat transfer is the lateral face of the cylinder | How does this impact how your model works?   * The model will only look at behavior inside the can * No mass balance between the can and the environment is required; light energy will not be considered * Can’t model can heating before food material heats * No convection term inside the can * No temperature changes due to external pressure changes   Slab-related heat transfer will not be considered |
| **What process parameters are you using for each of the food materials?**  Density, heat capacity, thermal conductivity, thermal diffusivity, heat transfer coefficient | | |
| * 1. **What microorganism is your program targeting? All of them? Only one? Why?**   My program targets C. Botulinum because it is the most dangerous and requires the most energy/time to reach the minimum sterilization specifications. Therefore, if this meets the sterilization requirements, all the microoganims will. | | |
| * 1. **What is the new time needed to commercially sterilize the product, and the time needed to cool the product to the required average temperature?**   The time to sterilize the product is 3.3 hours, the time to cool the product is 1.59 hours. | | |
| * 1. **What optimum temperatures were used for sterilization to retain nutrients? How do you know this is the optimum? Compare the optimum between the original (200 fill temperature) with the alternate (180 fill temperature).**   The optimum temperature for the alternate fill temperature is 118.3 degrees C and it takes 3.3 hours.  The optimum temperature for the original fill temperature is 118.3 degrees C and it takes 2.94 hours. | | |
| * 1. **Insert graph of the heating and cooling profile of the center of the can during the process. How do specific physical properties of the food impact this graph?** | | |
| * 1. **Insert graph of the biologic activity profile in the product at the center of the can versus time. Why would the center of the can make the most sense to monitor?** | | |
| * 1. **Insert graph of the average nutrient activity profile throughout the entire can versus time. Why would we use the average nutrient content across the can rather than at a single point?** | | |
| **How do parameters such as food composition, thermal properties of the food, geometry (can size) and processing parameters (times and temperatures) seem to impact the heating profile?** | | |
| **The larger the can, the harder it is to heat the center. The bigger the can, the longer to cool. The more water, the harder to heat as water has a large heat capacity.** | | |
| **How did you test how these properties affected the heating profile?** | | |
| I changed the parameters in the model and looked at the time, but my final model did not include these tests. | | |
| **For your process, how are Vitamin B1 and Vitamin C affected? How much of these Vitamins remain? How much more Vitamin loss is there in the new process (180 degree fill temp, than the original 200 degree fill temp?)** | | |
| For the most part, the vitamins remained intact. For 200F, The total reduction in Thiamine is 1.67.  The total reduction in Ascorbic Acid is 0.35.  The total reduction in Cobalamin is 0.20.  For 180F, The total reduction in Thiamine is 1.67.  The total reduction in Ascorbic Acid is 0.35.  The total reduction in Cobalamin is 0.20.  As such, there is not much change in the vitamin loss between the two processes. | | |
| **What is your estimate of additional energy and time costs due to the impacted filling temperature for your product?** | | |
| As you need to heat it to a higher relative temperature, you need to heat it longer, so the energy and time requirements will increase. | | |
| **What recommendations would you make to the systems engineer, R&D, and microbiology to improve costs and efficiencies on this line moving forward?** | | |
| The team should aim to sterilize before it enters the can, including a drip flash heating and cooling to prevent having varying levels of sterilization and nutrients throughout the geometry of the can. | | |