FOOD PROPERTIES: ACCESS AND CONTRIBUTE

(A crowdsourced database for predictive properties of food materials)

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SECTION 0: INTRODUCTION

OVERVIEW OF DATABASE

What is in this database?

This database is a collection of biomaterial data and formulas from published, peer-reviewed literature. Both data and formulas are associated with each other to a reasonable extent that provide predictive plots that allow users to quickly, efficiently discern trends across several properties and materials. Users may store, retrieve, and visualize various properties and materials while also being able to edit the composition of each material tuned to their specific application. Overall, this database is a collaborative, comprehensive repository of biomaterial data and formulas. Registered users may contribute and validate data, allowing the database to be ever expanding.

Who can use this database?

The database is designed for a wide range of users including researchers, engineers of food science, nutritionist, as well as educators and students. Anyone with the need or intent to understand the physical properties of food materials and their relationships benefit from using this database.

Where should I start?

Depending the user's intentions for this database, starting points may vary. Users should read through **Section 2** of this manual to grasp the output of this database and get an introductory understanding. Users specifically looking to contribute data will benefit from **Section 3** and **Section 4**. For users with limited background in food properties or bioengineering may find **Section 6** most helpful. However, to understand the application of this database, *Use Examples* in **Section 5** will be most beneficial.

USE IN MANUFACTURING

1. Directionality in design
2. Predict "what if" scenarios for reformulations
3. Feasibility studies (trying out new ideas)
4. Quick answers, bypassing research
5. Storing proprietary materials

USE IN RESEARCH

1. Deeper understanding of materials
2. Quick access, bypassing detailed literature search
3. Quick estimation followed by sensitivity analysis
4. When you contribute, your work reaches everyone instantly

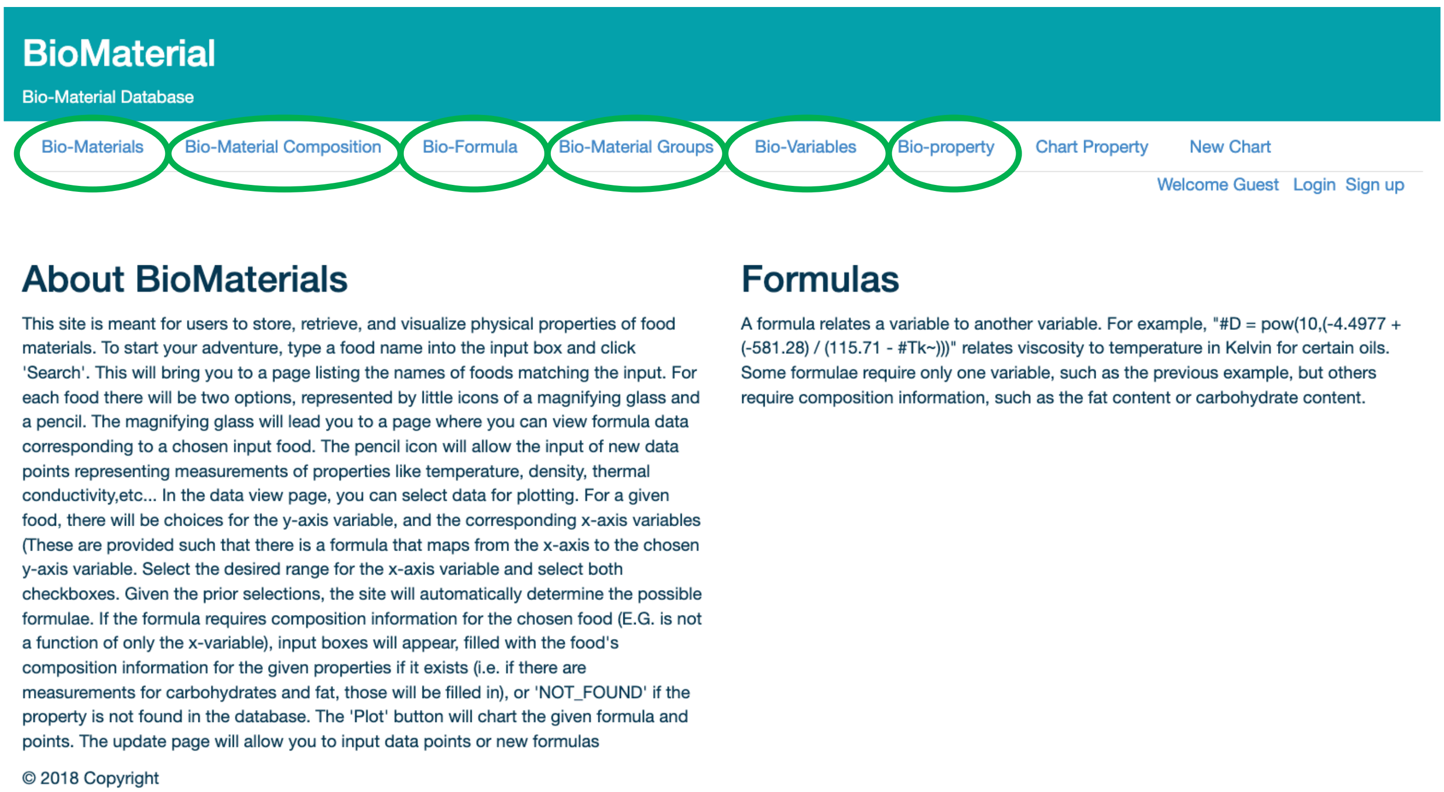
USE IN INSTRUCTION

1. Deeper understanding of materials. See example on Page
2. Deeper understanding of properties
3. Cross-property understanding
4. Complement a properties course with active learning
5. Learning modules for properties

SECTION 1: GETTING ORIENTED

This database has potential to aid in aspects of manufacturing, research, and education as detailed on the previous page. It is important that the user is familiar with the layout of the database and understands where to begin and find desired information. The goal of Data Retrieval is to deliver fast, accurate, and helpful predictions of various properties of materials. For new users, understanding where to find these materials, properties, and variables is crucial to their benefit in this resource.

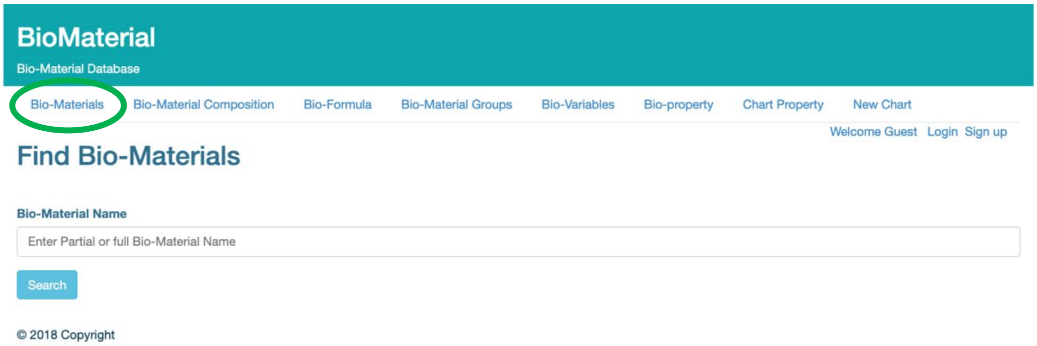
Below are the tabs of the website that contain searching methods of all the materials, properties, formulas, and variables in the website. Descriptions of each tab and their function are as follows:



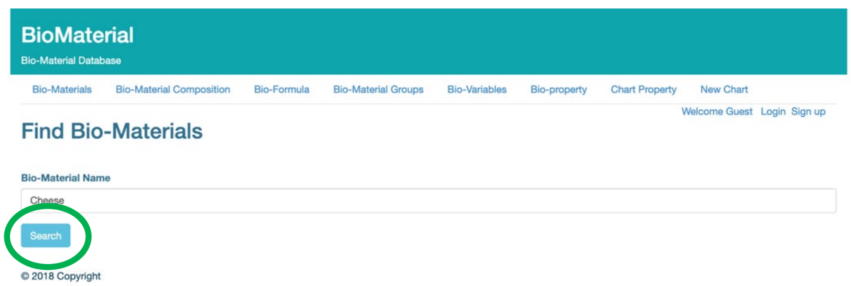
SECTION 1.1: BIO-MATERIALS

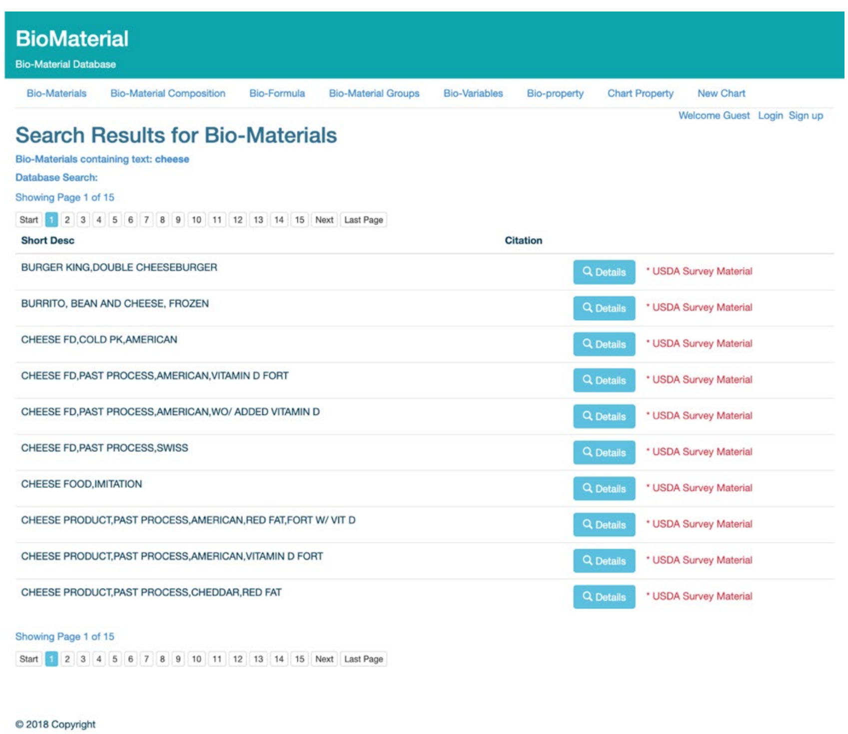
This section contains a search method for all the food items in the database.

Step 1: Selecting the "Bio-Materials" tab will take the user to this page:

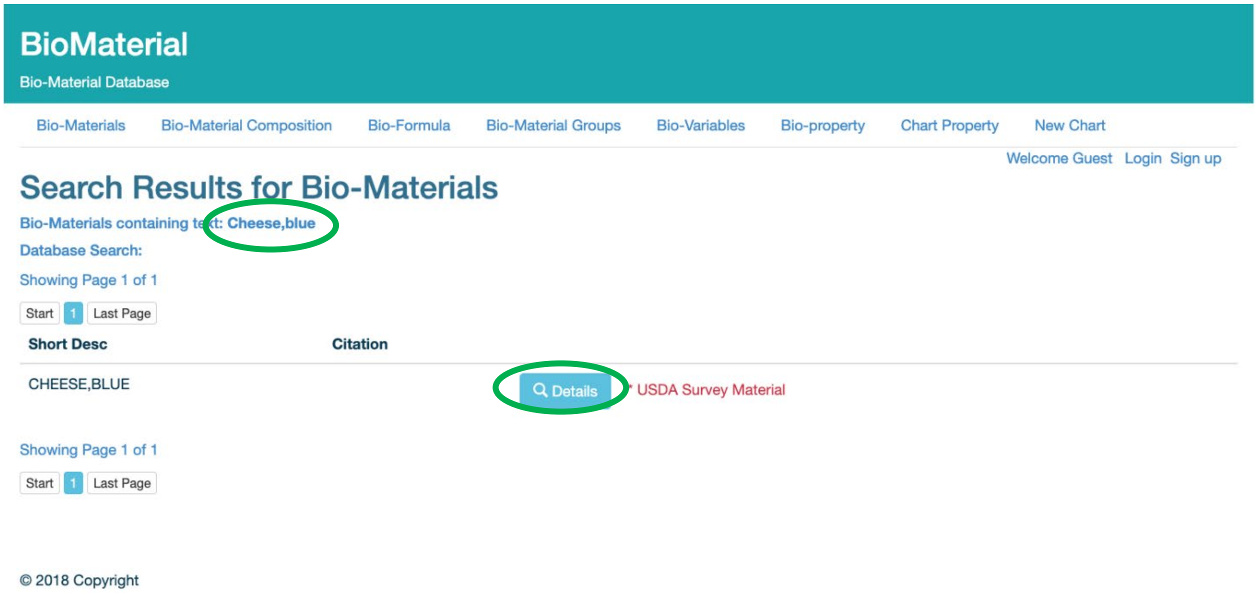


Step 2: Type the name of the desired food and select "Search". Here, the keyword "*Cheese*" was input. Note that the search results are alphabetized and includes all products that include the keyword in its name.

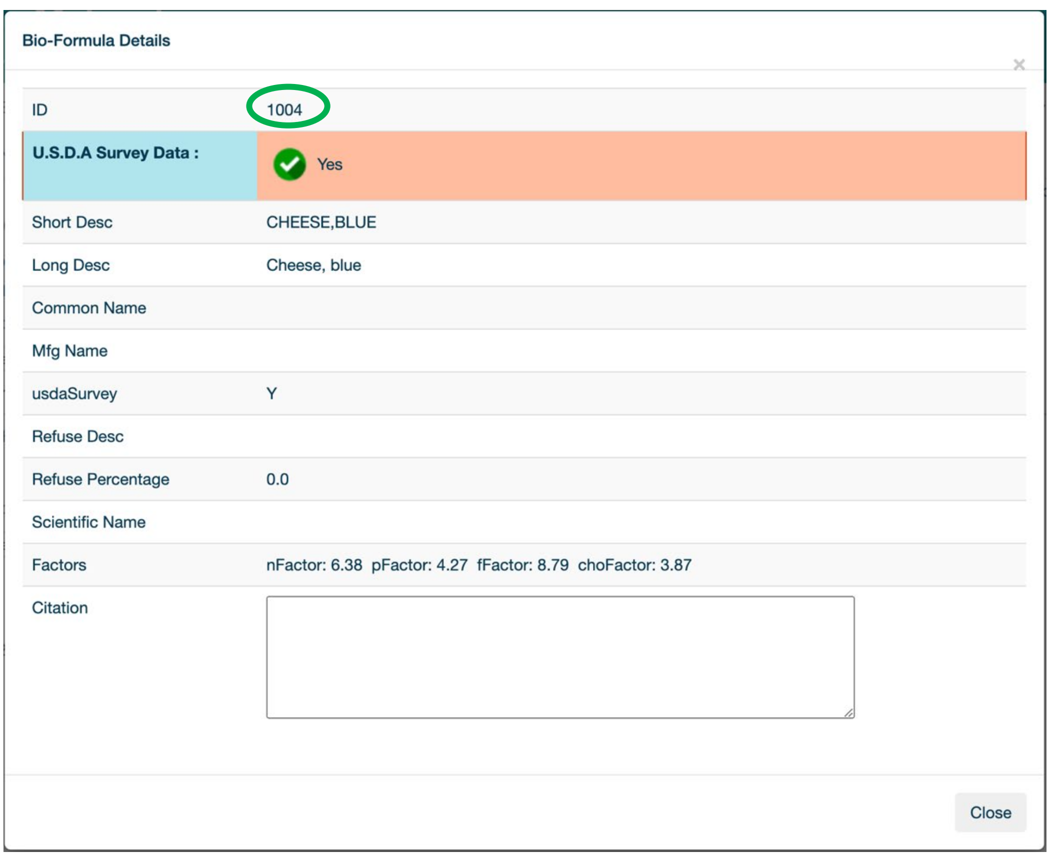




Step 3: To reduce the amount of search results, include further description by appending the modifier or descriptor to the end of the word, separating by a comma. Ensure no spaces between the words, just a single comma. In this example, the keyword "*Cheese,blue*" was entered to find Blue Cheese (instead of "Cheese" alone). Refer to **Section 6.1** for further details on search terms.



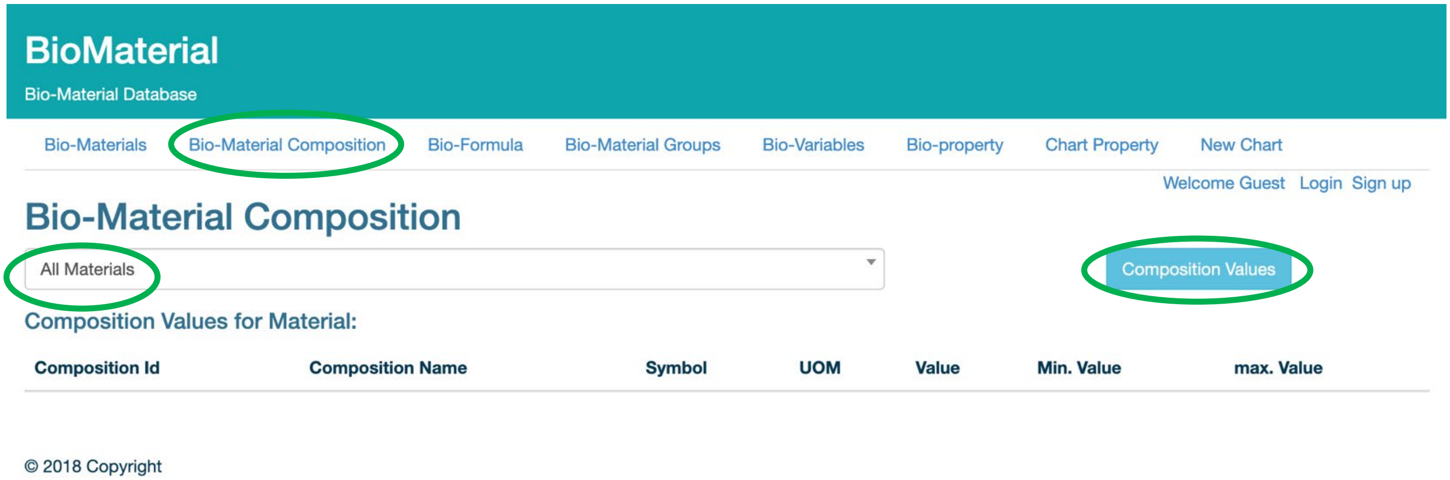
Step 4: Select "Details" to inspect the item in higher detail. Use the ID number to refer to this exact item in **Section 2: Data Retrieval**. In this example, the ID number for Blue Cheese is 1004 (circled below).



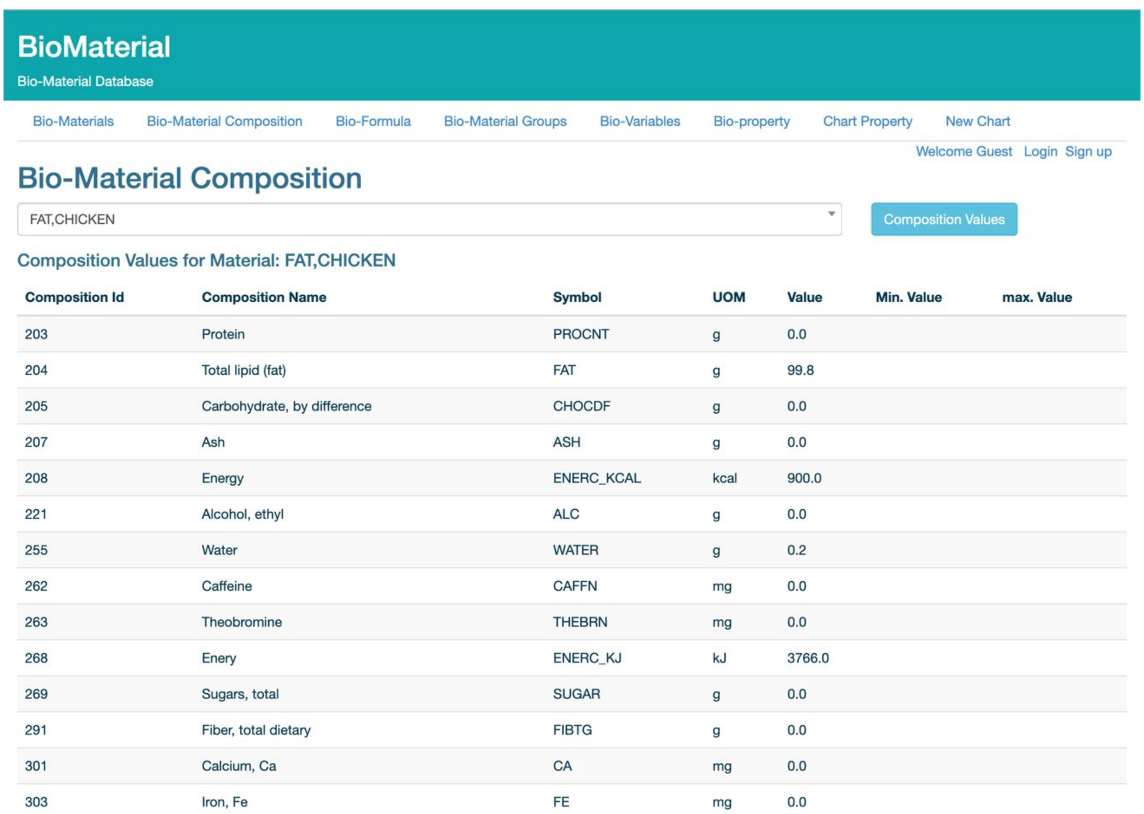
SECTION 1.2: BIO-MATERIAL COMPOSITION

The Bio-Material Composition page allows users to access detailed compositional data of various products. Specific information, such as protein, water and cholesterol content value, can be found with ease. This page is essential for users to understand the precise makeup of products.

Step 1: Selecting the "Bio-Material Composition" tab (circled below) will take the user to this page:



Step 2: Enter a biomaterial or food product in the "All Materials" tab circled above. Select "Composition Values" to bring the following page containing the values. (Here, the ID number "*4542*" was used instead of "*FAT,CHICKEN*", but either will work).

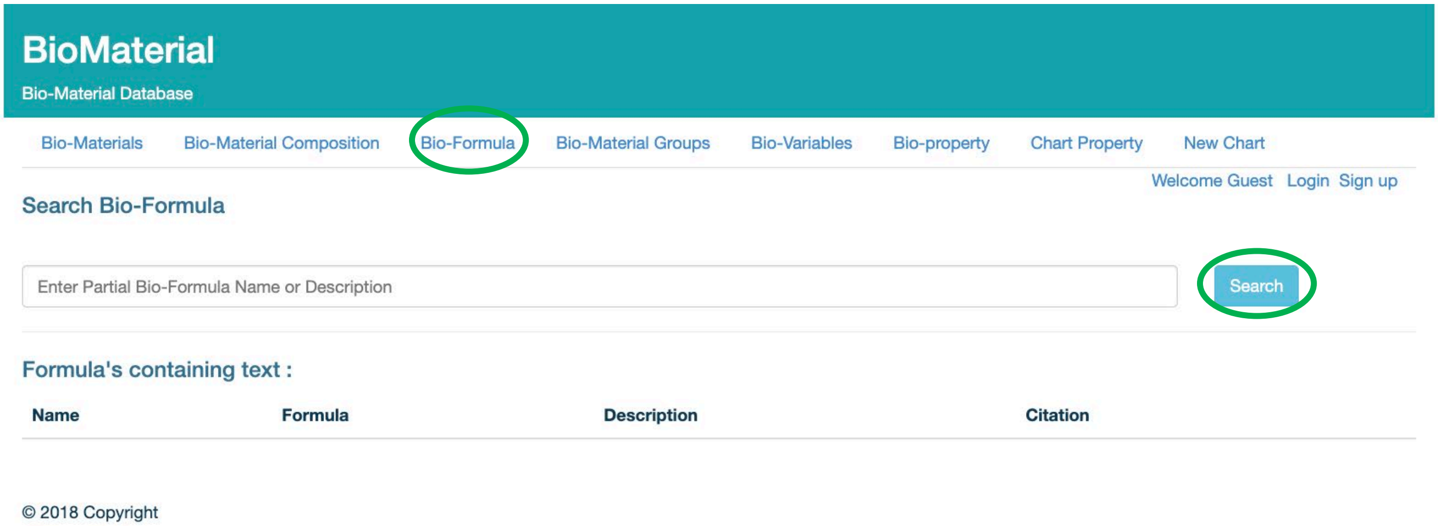


Composition Id	Composition Name	Symbol	UOM	Value	Min. Value	max. Value
203	Protein	PROCNT	g	0.0		
204	Total lipid (fat)	FAT	g	99.8		
205	Carbohydrate, by difference	CHOCDF	g	0.0		
207	Ash	ASH	g	0.0		
208	Energy	ENERC_KCAL	kcal	900.0		
221	Alcohol, ethyl	ALC	g	0.0		
255	Water	WATER	g	0.2		
262	Caffeine	CAFFN	mg	0.0		
263	Theobromine	THEBRN	mg	0.0		
268	Enery	ENERC_KJ	kJ	3766.0		
269	Sugars, total	SUGAR	g	0.0		
291	Fiber, total dietary	FIBTG	g	0.0		
301	Calcium, Ca	CA	mg	0.0		
303	Iron, Fe	FE	mg	0.0		

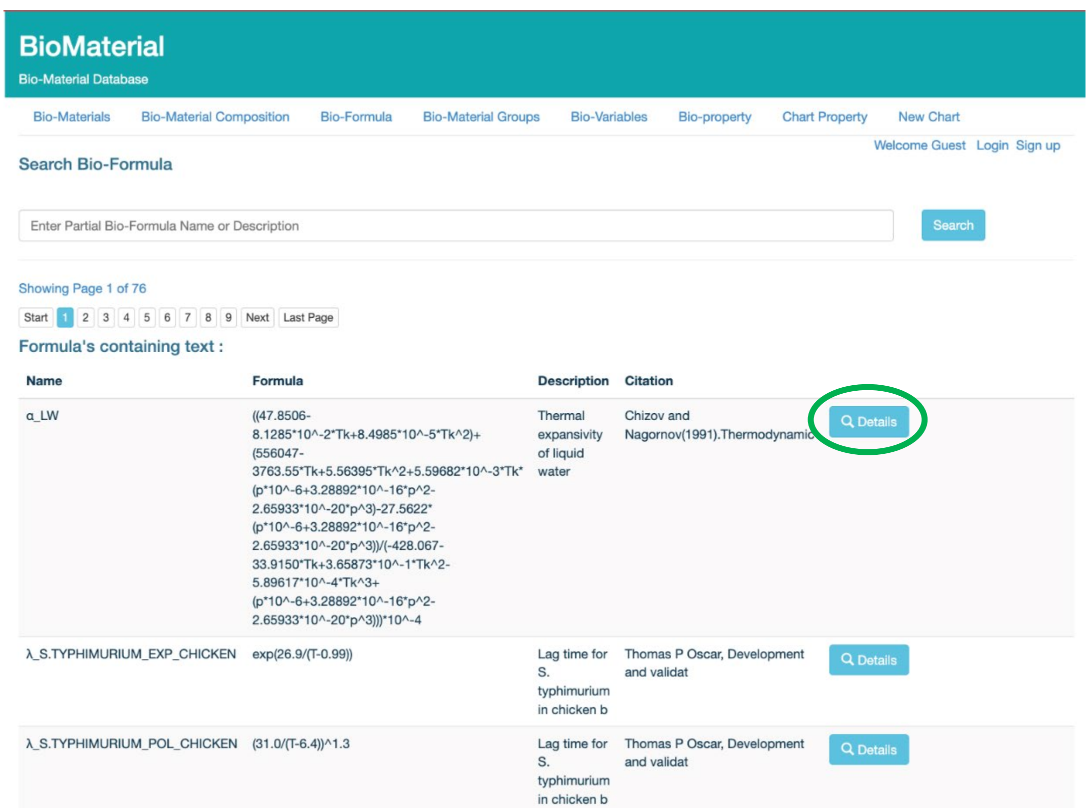
SECTION 1.3: BIO-FORMULA

The Bio-Formula page enables users to locate various predictive formulas related to multiple variables pertaining to the respective material. The functionality is essential for users who need to apply predictive modeling and simulates the behavior of products under different conditions. To begin, select the "Bio-Formula" tab and search for the desired formula. Select "Details" for additional information regarding the description and citation of the formula.

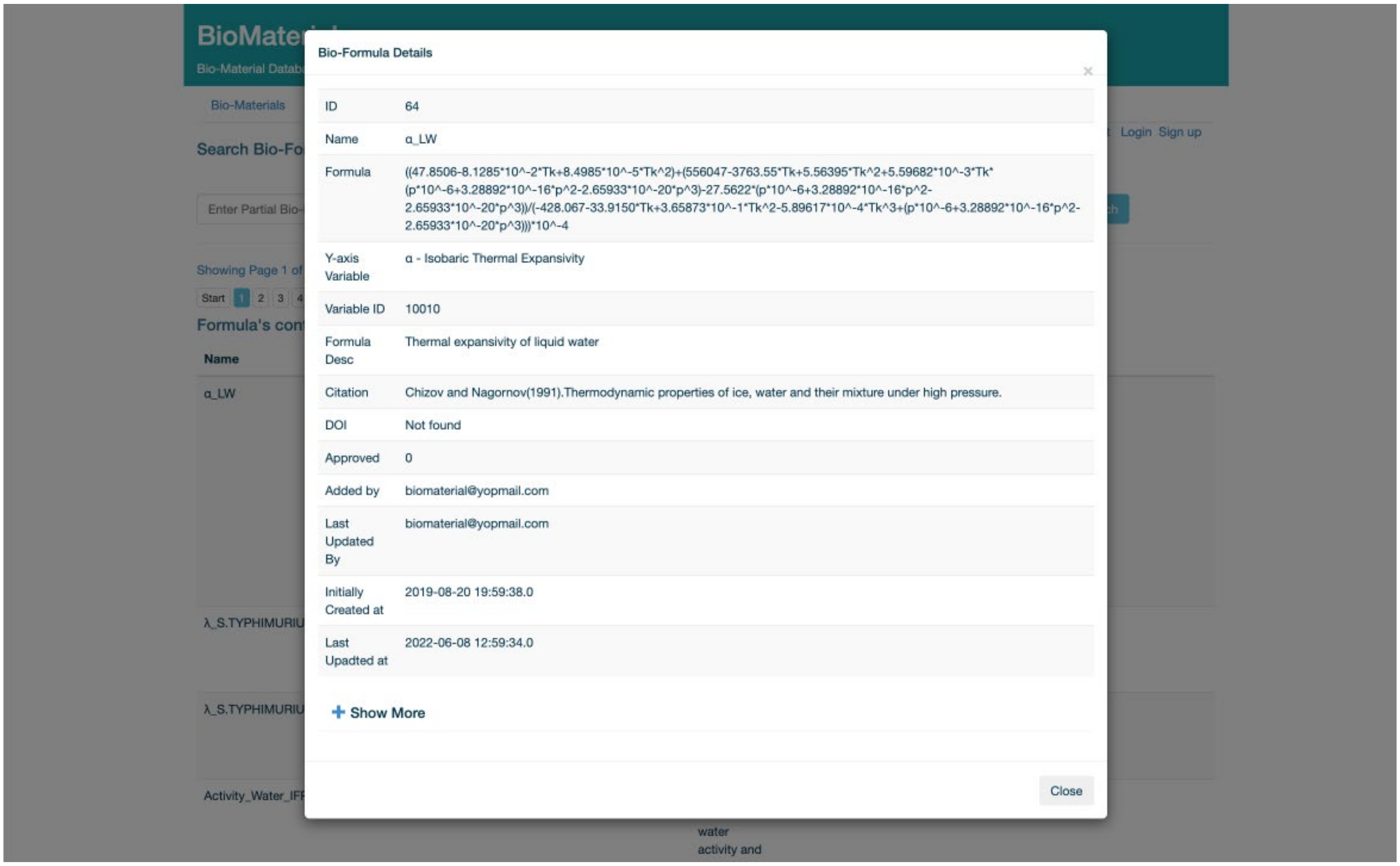
Step 1: Selecting the "Bio-Formula" tab (circled below) will take the user to this page:



Step 2: Selecting "Search" (circled above) will appear all the formulas in the database. Enter the formula name or description in the search tab to narrow search results.



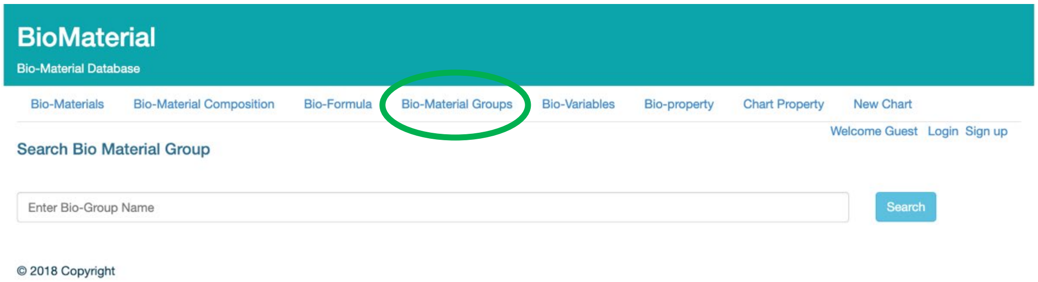
Step 3: Selecting "Details" of a given group, then "+ Show More" in the pop-up tab will reveal all associated biomaterials, bio-groups, and bio-formulas.



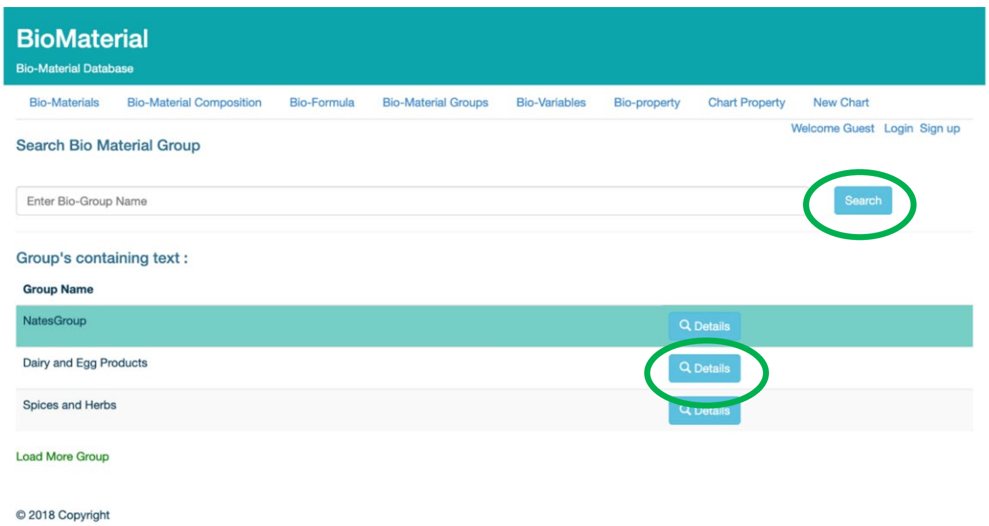
SECTION 1.4: BIO-MATERIAL GROUPS

The Bio-Material Group search function enables users to efficiently locate all the groups and the associated materials within the database. This feature helps streamline the process of finding relevant materials belonging to specific groups.

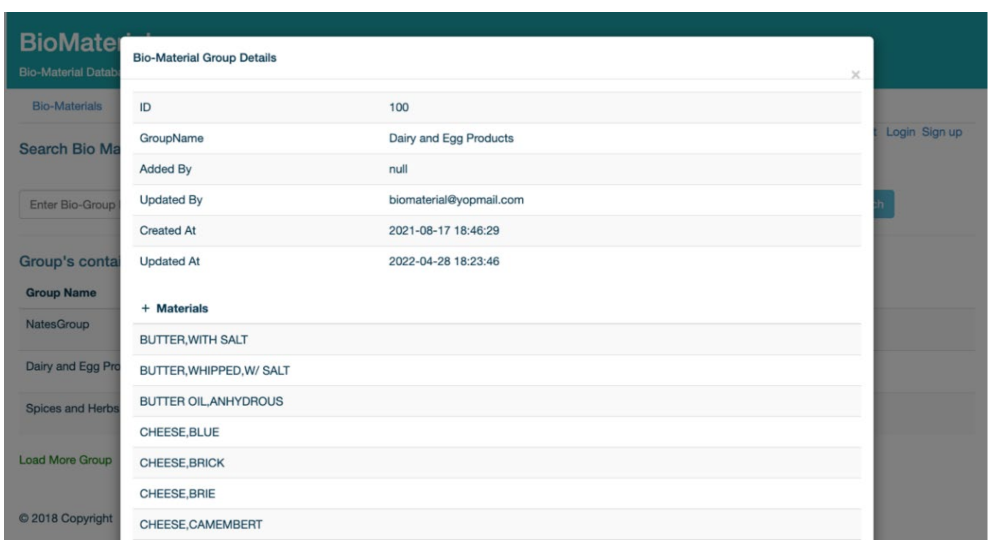
Step 1: Selecting the "Bio-Material Groups" tab (circled below) will take the user to this page:



Step 2: Selecting "Search" will appear some of the groups in the database, to reveal more select "Load More Groups". Enter the group name or description in the search tab to narrow search results.



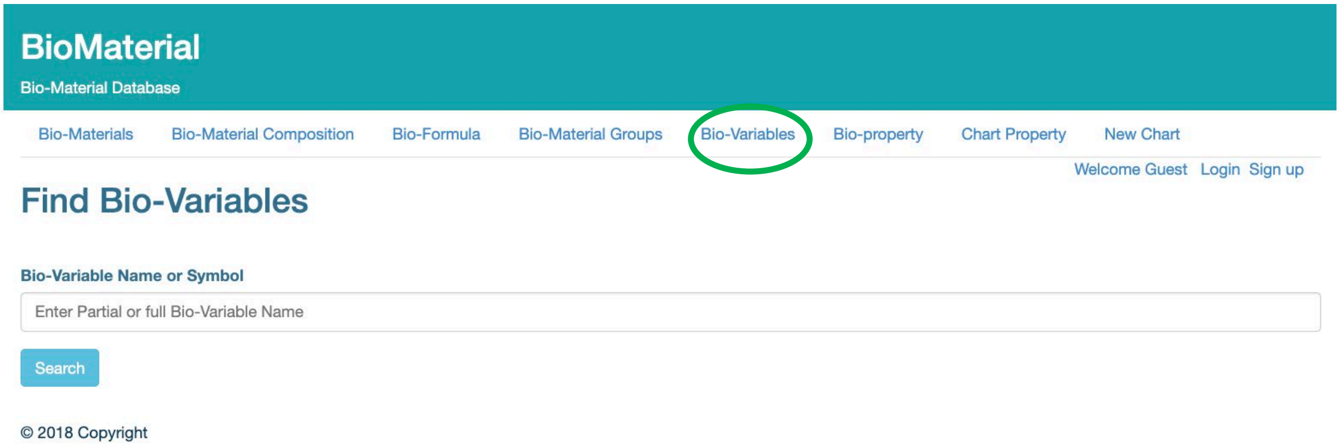
Step 3: Selecting "Details" (circled above) of a given group, then "+ Materials" in the pop-up tab will reveal all the materials associated with the group:



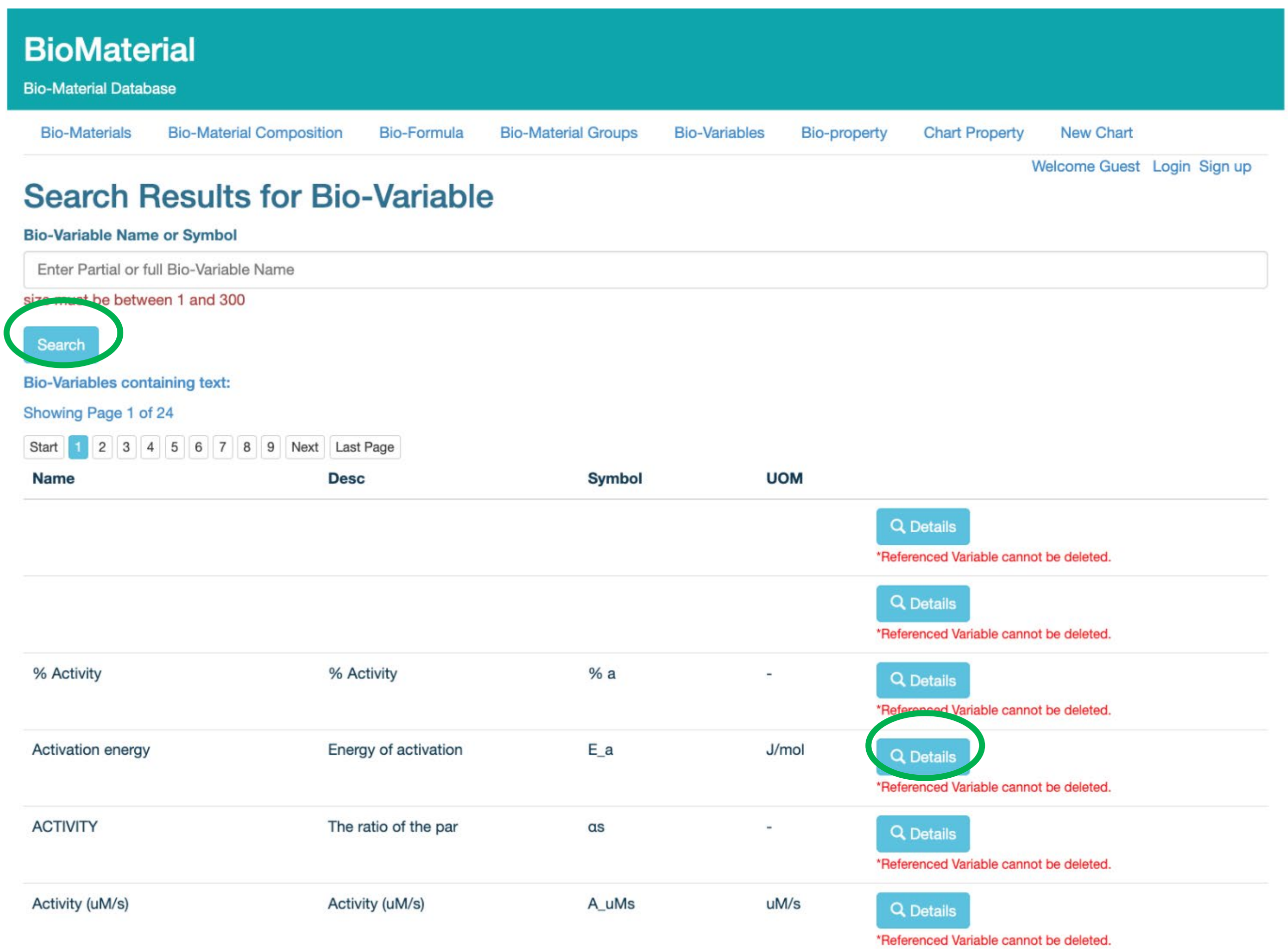
SECTION 1.5: BIO-VARIABLES

The Bio-Variables search function enables users to find all variables used in the database. This feature provides an organized, efficient method to retrieve and review different bio-variables and their relation to formulas.

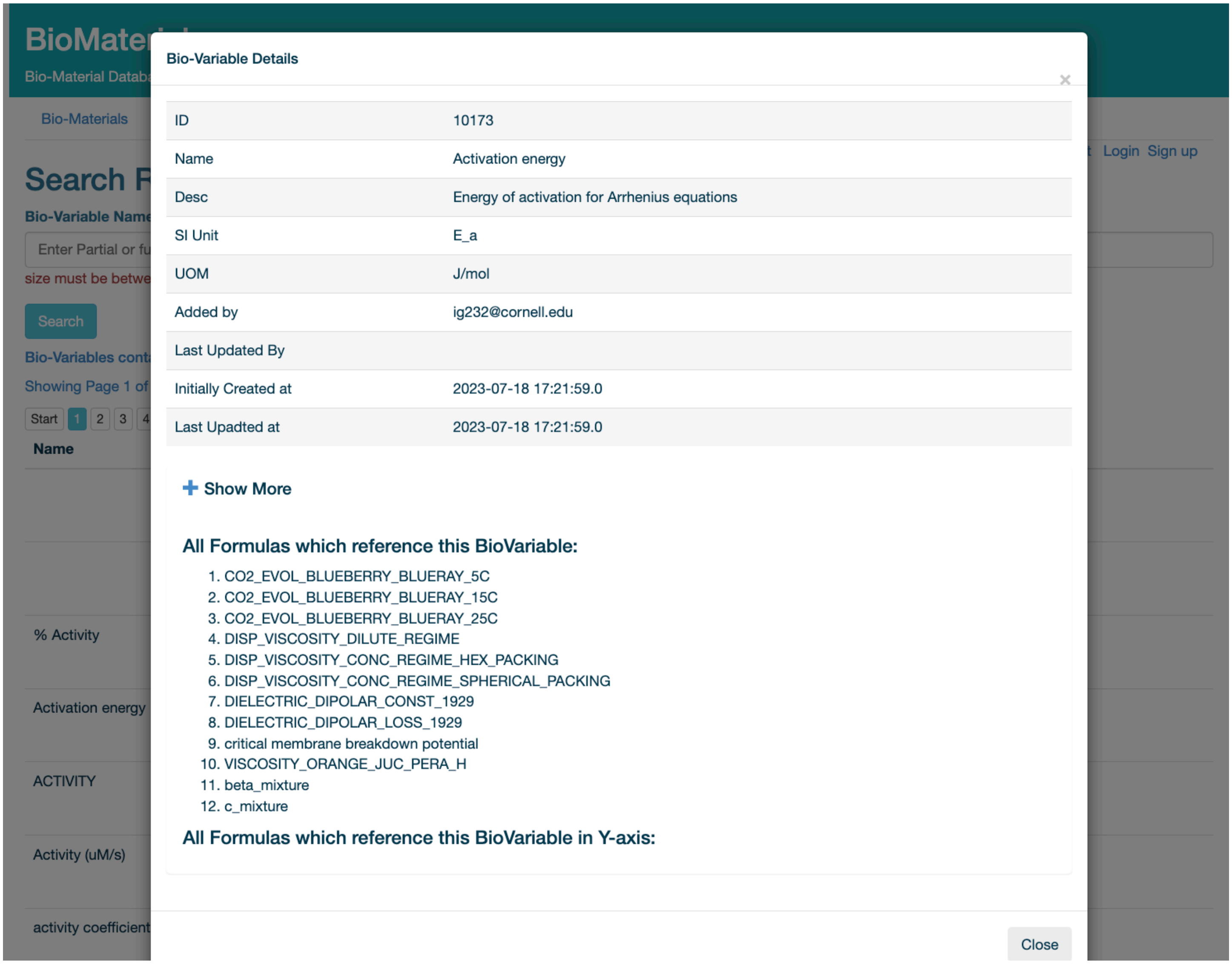
Step 1: Selecting the "Bio-Variables" tab (circled below) will take the user to this page:



Step 2: Selecting "Search" will appear an alphabetized list of variables in the database.



Step 3: Select "Details" and "+ Show More" reveals all the formulas and Y-axis variables that use this bio-variable.

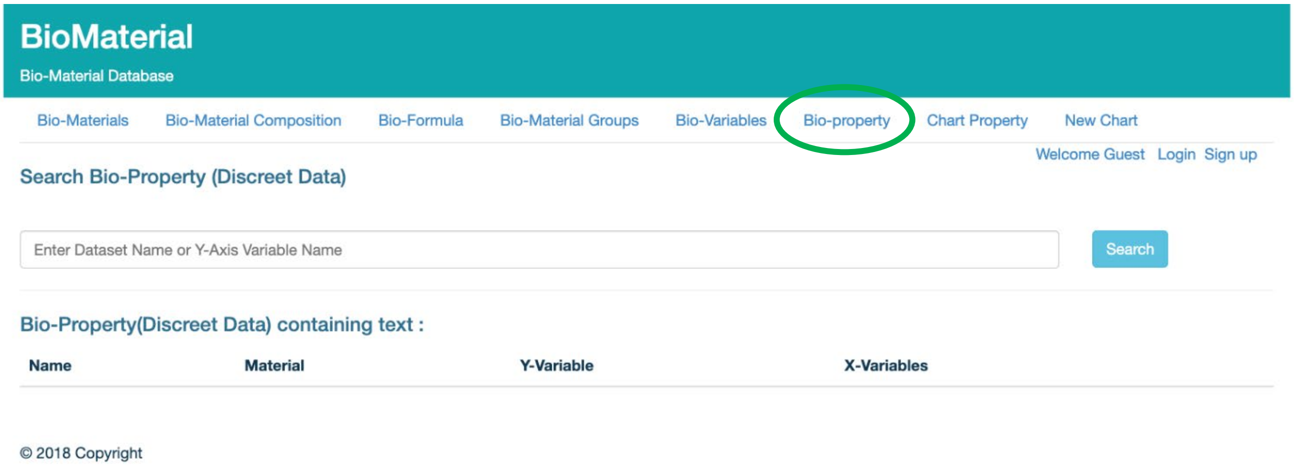


Helpful Tip: Additionally, descriptions of each variable used in formulas can be found in the Index of this manual. See page X.

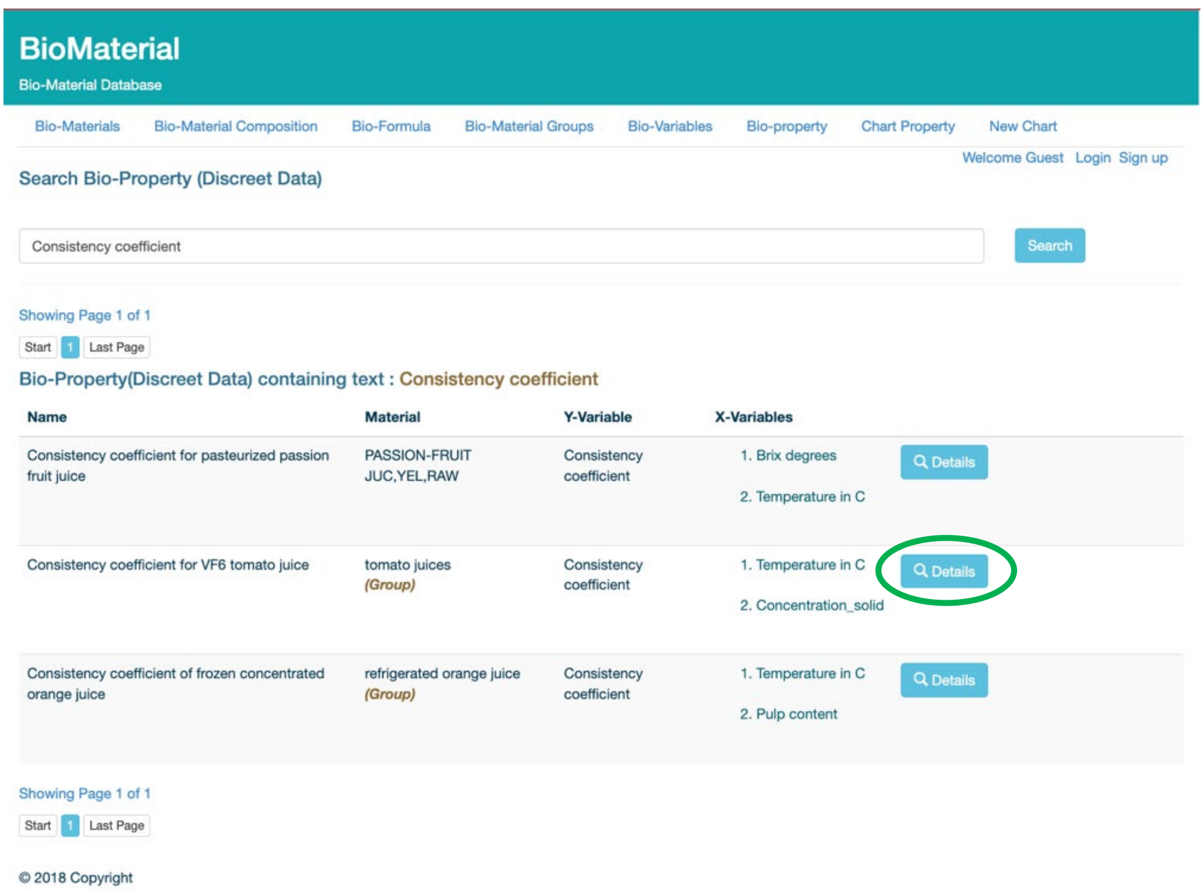
SECTION 1.6: BIO-PROPERTY

The Bio-Variables search function allows users to display the discrete data for a variable or dataset in the database. Enabling users to quickly plot this data helps them efficiently visualize the recorded and measured data of this database.

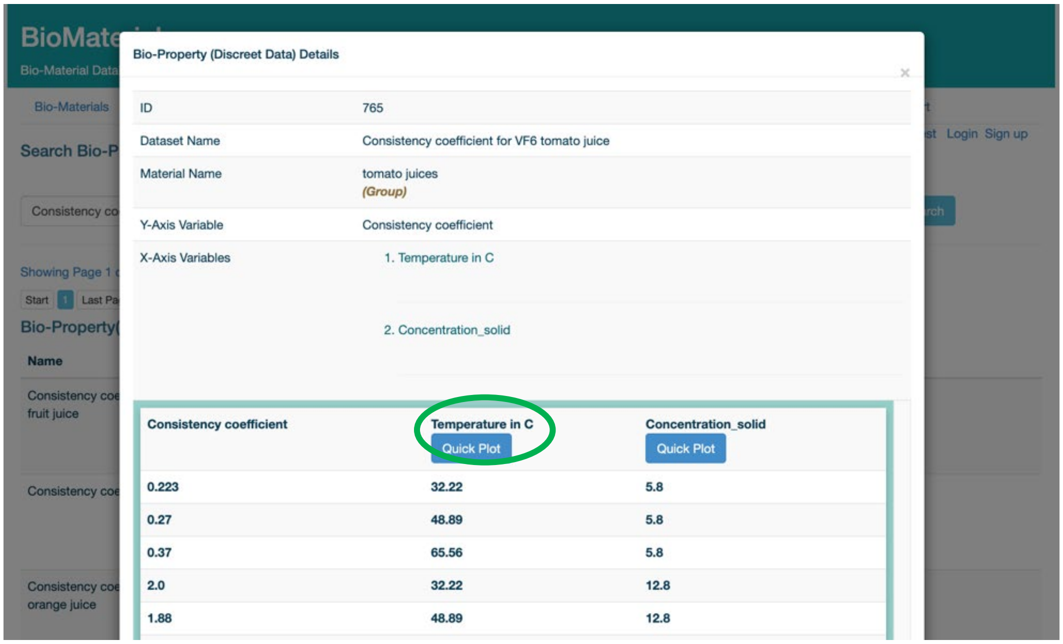
Step 1: Selecting the “Bio-Property” tab (circled below) will take the user to this page:



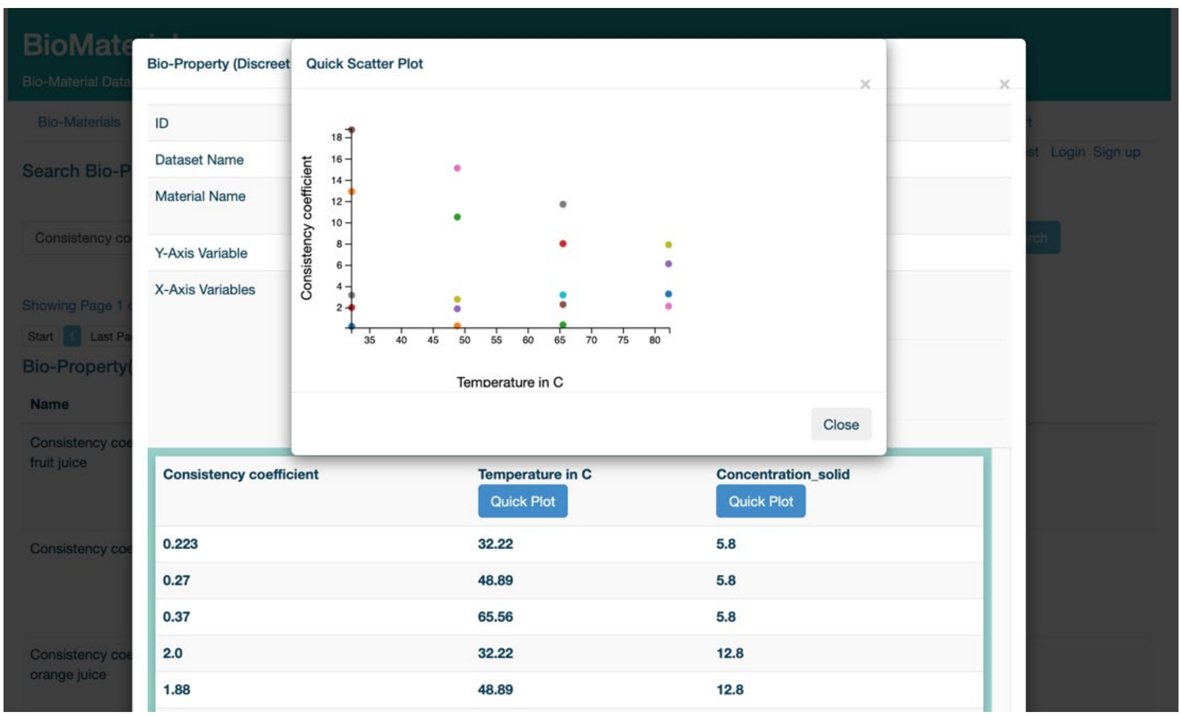
Step 2: Begin typing in a desired property. See the “Glossary” section of this manual for listed properties. Below, “consistency coefficient” is used.



Step 3: Of the results, select "Details".



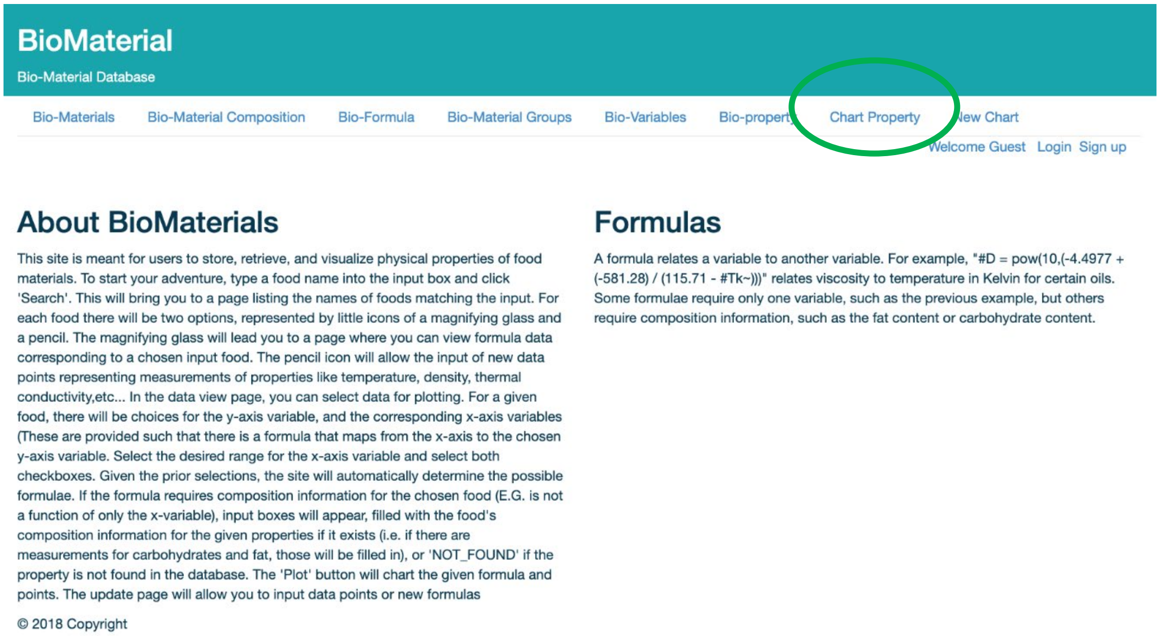
Step 4: Select "Quick Plot" of either options available.



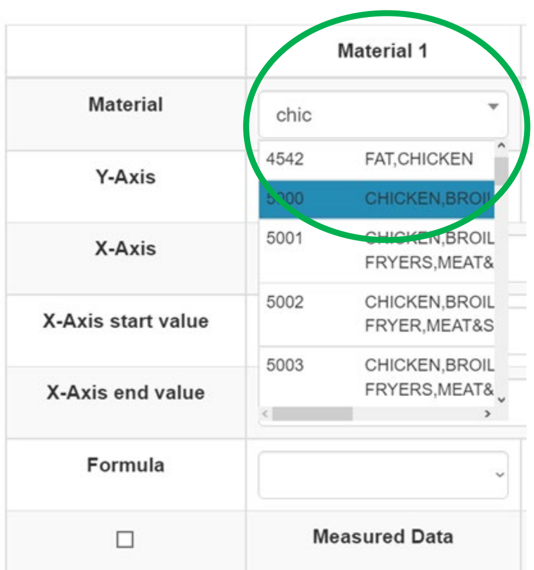
SECTION 2.1: ESTIMATING PROPERTIES OF A FOOD MATERIAL VS. TEMPERATURE, COMPOSITION, ETC.

This section is an introduction to the charting portion of the database that allows users to predict how a specific property changes with varying conditions. Understanding of these trends and variations will allow users to optimize their own condition parameters that can be crucial to developing products or improving upon existing ones.

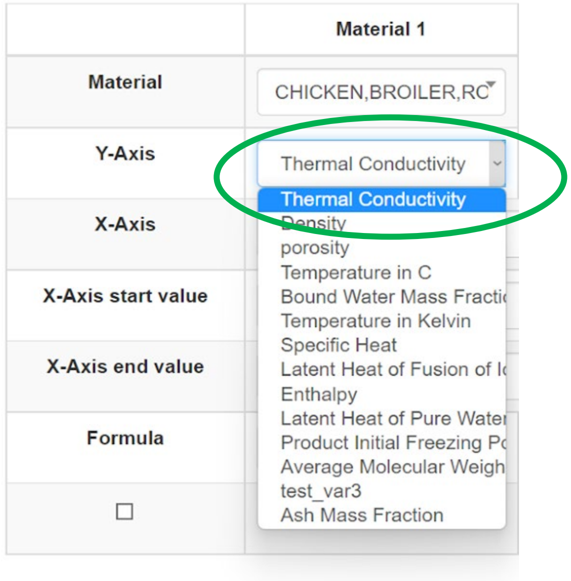
Step 1: Go to http://167.71.237.183:8080/home
Step 2: Select "Chart Property" below.



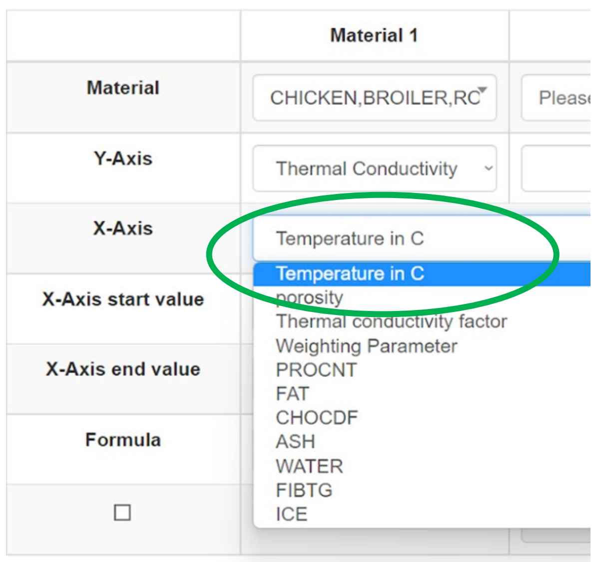
Step 3: Under "Material 1." start typing the material name.
Step 4: Select from the suggested list in the dropdown.



Step 5: In the Y-axis row, under your chosen material, click on dropdown menu and select the property of your interest. There may be a delay (15-20 s) before the next step is possible—please wait for it.



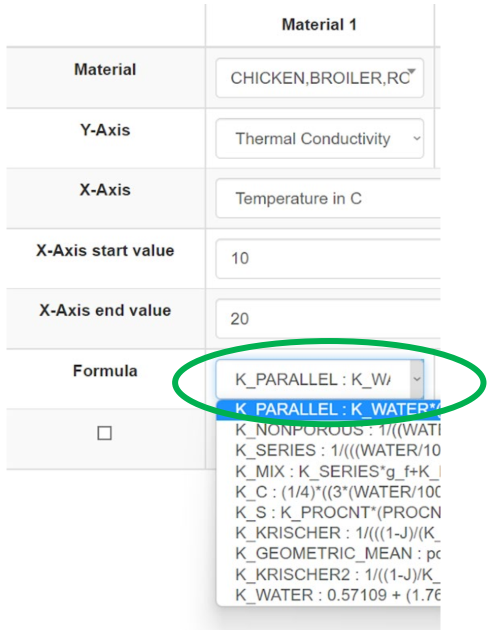
Step 6: In the X-axis row, under your chosen property, click on the dropdown to select the variable against which you will plot your property.



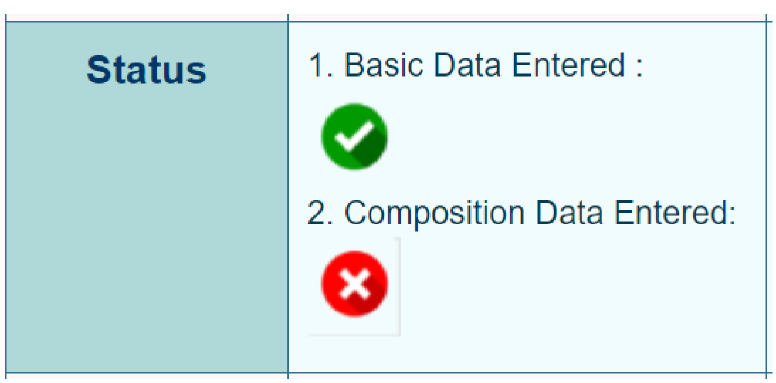
Step 7: In the X-Axis start value, under your chosen property, enter the lowest value of the variable you chose in Step 6.

Step 8: In the X-Axis end value, under your chosen property, enter the highest value of the variable you chose in Step 6.

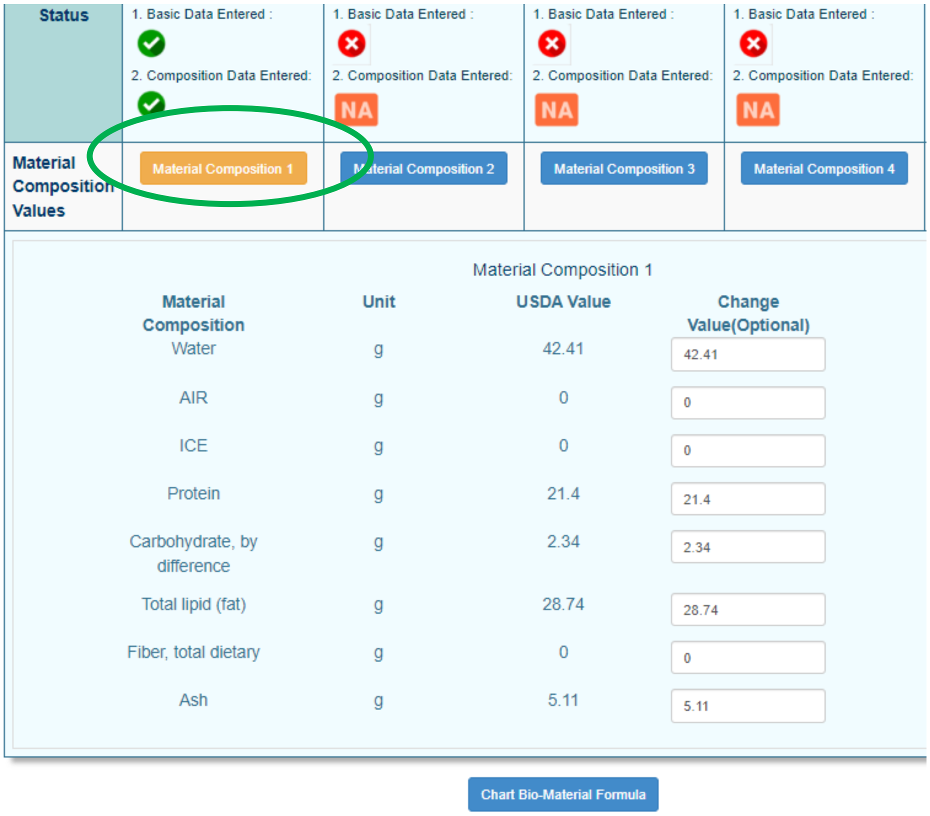
Step 9: In the Formula row, under your chosen property, click on the dropdown to select among the prediction formulas you want to use for your selected property. Again, there may be a delay (15-20 s) for the dropdown list to appear—please wait for it.



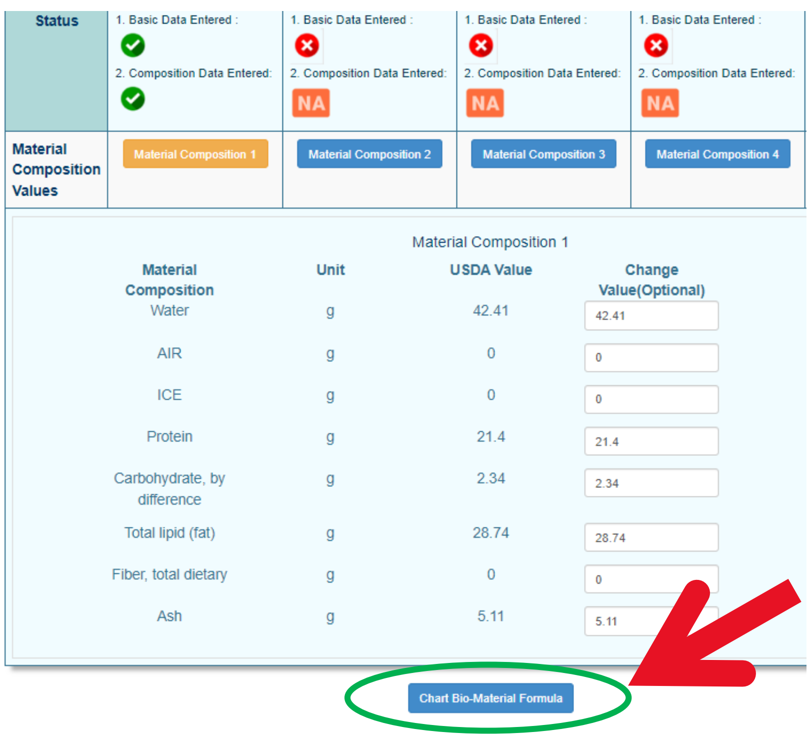
Step 10: Check against the "Status" row to make sure the button below "Basic Data Entered" is green



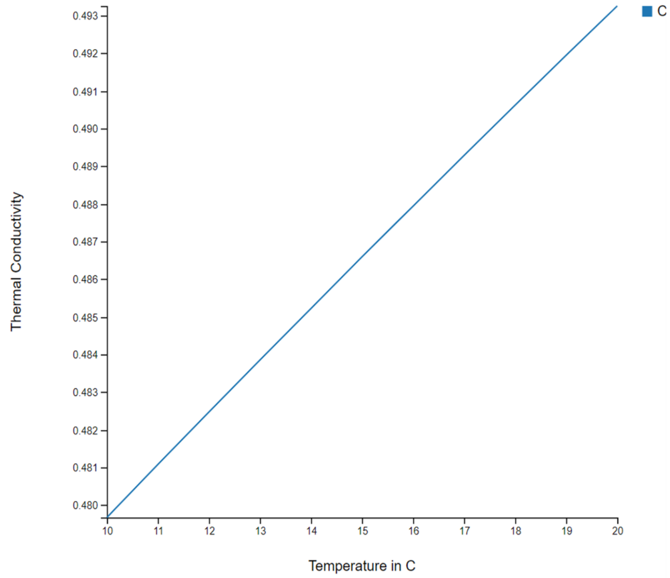
Step 11: Click on "Material Composition 1" to see a window open up showing all the composition data for the selected material from the database. This window will also show variables from the formula that are not selected in 'X-axis' row. You can proceed or change a composition variable by typing your value under the "Change Value" column.



Step 12: Click on "Chart Biomaterial Formula" to plot



Step 13: You should see a plot like the one below:

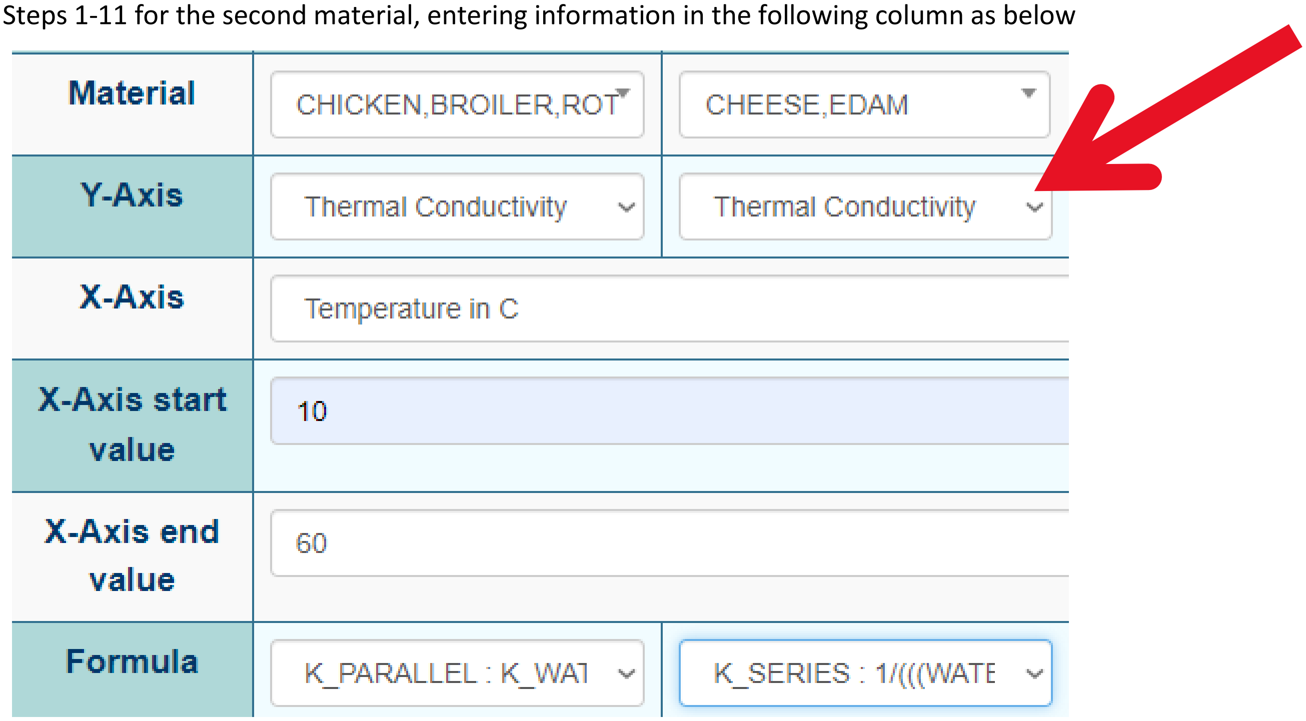


SECTION 2.2: ESTIMATING ONE PROPERTY FOR MULTIPLE MATERIALS

This section allows users to compare a single property across different food materials. This comparison may help in selection of material by identifying which ones meet a desired criterion, depending on the application. Charting these materials and their respective properties may reveal how they respond to certain conditions and identify trends and directionality that are valuable in formulating new or changing existing products.

Step 1: Repeat Steps 1-11 for one material

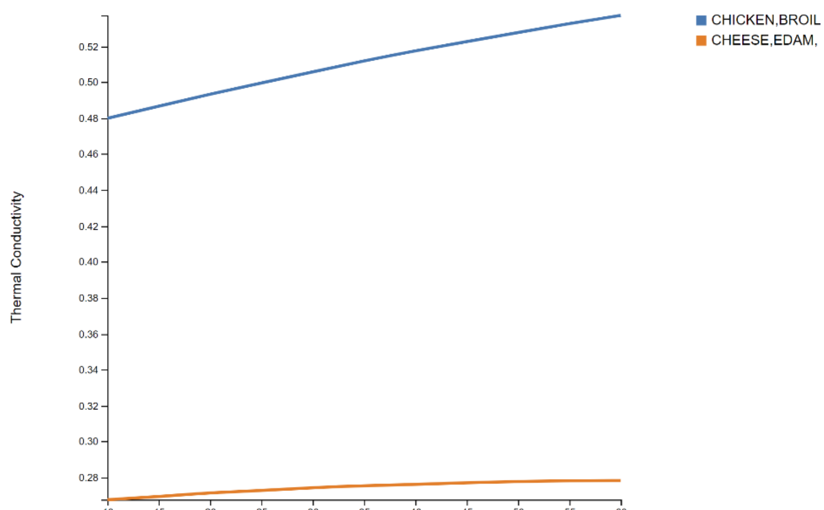
Step 2: Repeat Steps 1-11 for the second material, entering information in the following column as below



Step 3: Repeat for up to five material-formula combinations.

Step 4: Click on “Chart Biomaterial Formula” to plot (**Section 1, Step 12**).

Step 5: You should see a plot like this below:



SECTION 2.3: ESTIMATING MULTIPLE PROPERTIES OF THE SAME MATERIAL

Estimating multiple properties of the same material allows users to gain a comprehensive understanding of how these properties interrelate and provides a holistic view that may be essential for optimizing processing methods, storage, and transportation of food product.

Step 1: Repeat Steps 1-11 for a material

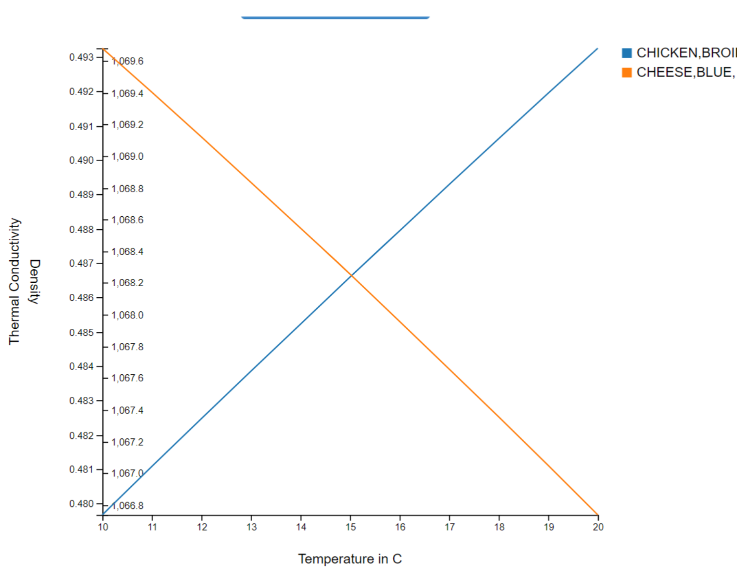
Step 2: Repeat Steps 1-11 for the same material, entering information in the following column as below. Starting from "Y-axis," entries will be different except for "X-axis" that has to stay the same.

	Material 1	Material 2
Material	CHICKEN,BROILER,RC	CHEESE,BLUE
Y-Axis	Thermal Conductivity	Density
X-Axis	Temperature in C	
X-Axis start value	10	
X-Axis end value	20	
Formula	K_PARALLEL : K_W/	RHO_MIX : 1/(((WAT
☐	**Measured Data**	--select

Step 3: Repeat for up to five materials.

Step 4: Step 12: Click on "Chart Biomaterial Formula" to plot

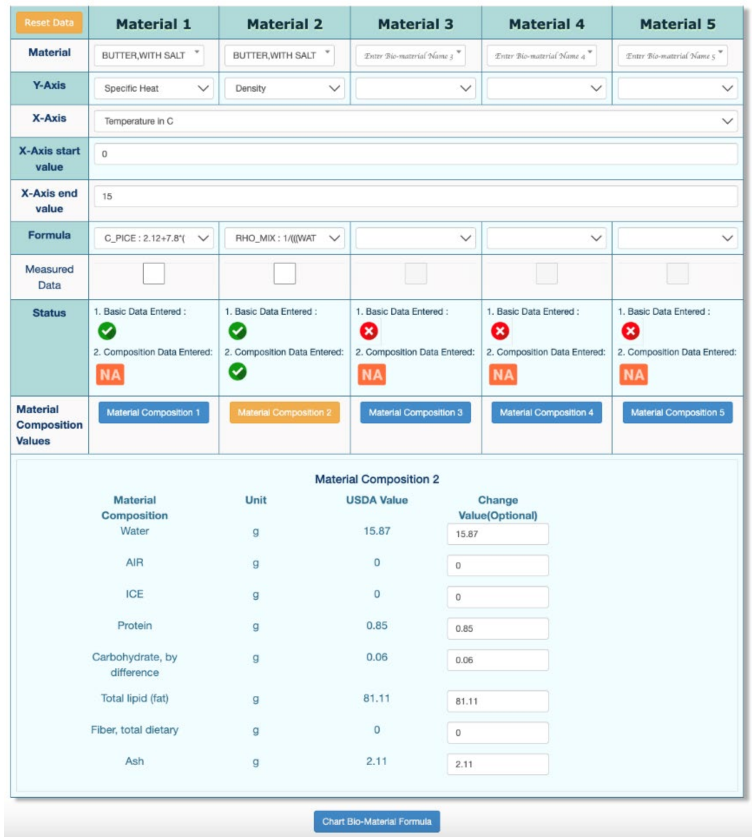
Step 5: You should see a plot like this below:



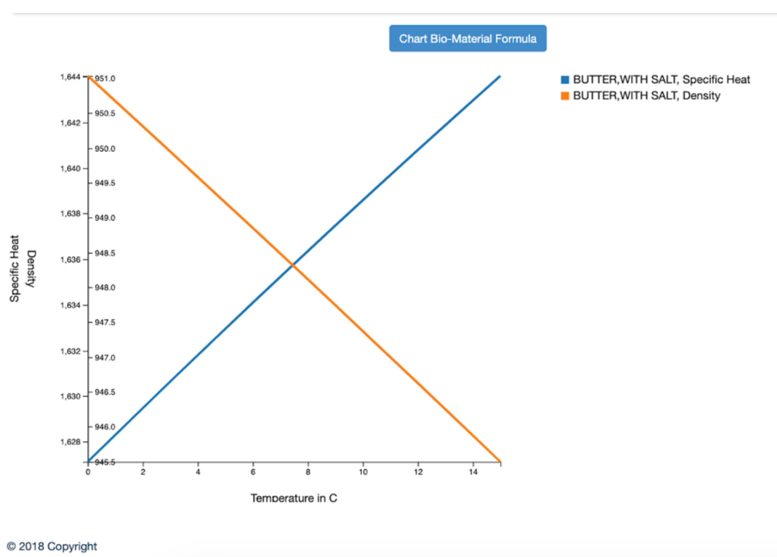
SECTION 2.4: VISUALIZING ONE PROPERTY VS. ANOTHER FOR THE SAME MATERIAL

This subsection is useful to the user by exploring the relationship between two specific properties of a material that may help identify potential correlations, trade-offs, and trends between two properties to provide insight into how they may influence each other or be affected by changes in composition and condition.

Step 1: Repeat Section 1: Steps 1-11 for a material in column 1 titled "Material 1".
Step 2: Repeat Section 1: Steps 1-11 for the same material in column 2 titled "Material 2", using the same material in column 1.



Step 3: Select "Chart Bio-Material Formula" to plot the material properties as shown below.

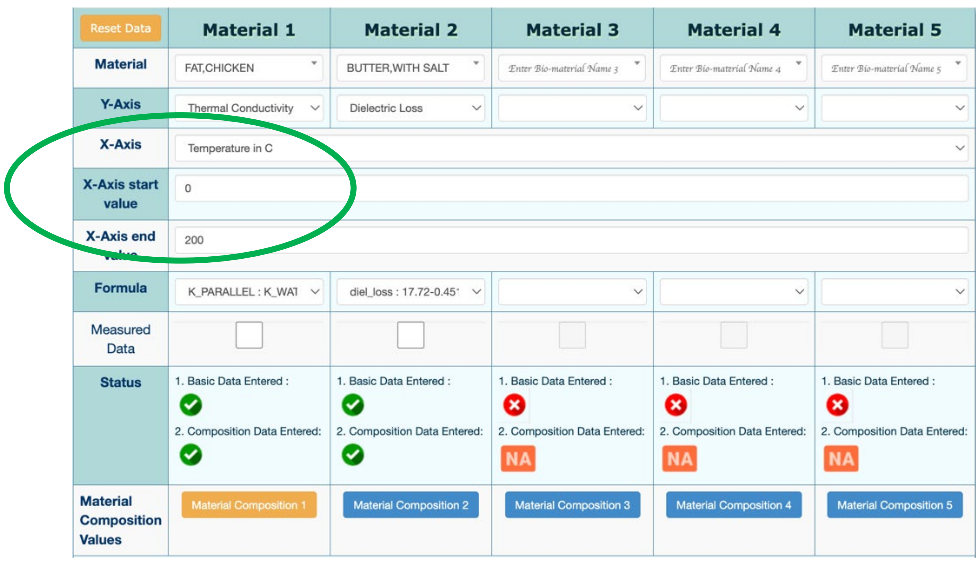


SECTION 2.5: VISUALIZING DIFFERENT PROPERTIES AND DIFFERENT MATERIALS

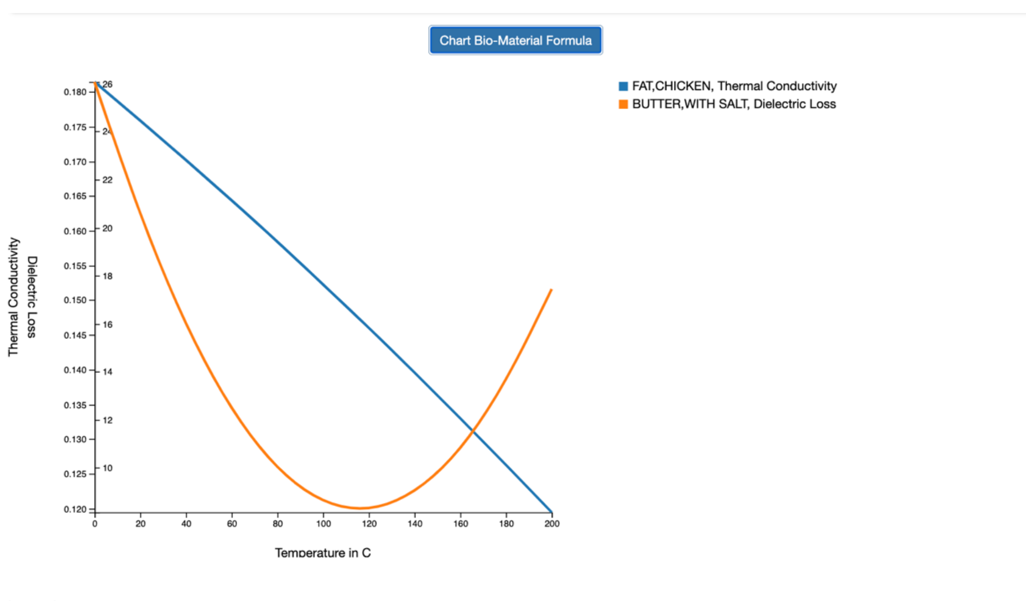
This subsection is helpful in providing a visual of the behavior of different materials during the cooking process. Understanding how certain properties tied to certain materials change as temperature increases is important in optimizing even and proper and precise cooking and heating.

For this section, it is helpful that the two materials chosen are associated with each other and that the respective properties are important to consider during the heating process. Here, chicken fat and salted butter are chosen with thermal conductivity and dielectric loss, respectively.

Step 1: Repeat Section 1: Steps 1-6 for a material in column 1 titled "Material 1".
Step 2: Repeat Section 1: Steps 1-6 for a different material in column 2 titled "Material 2".
Step 3: Ensure that the X-axis chosen is "Temperature in C" and that the range covers the standard cooking temperatures for the given material. Continue by repeating Section 1: Steps 7-11 for both materials.

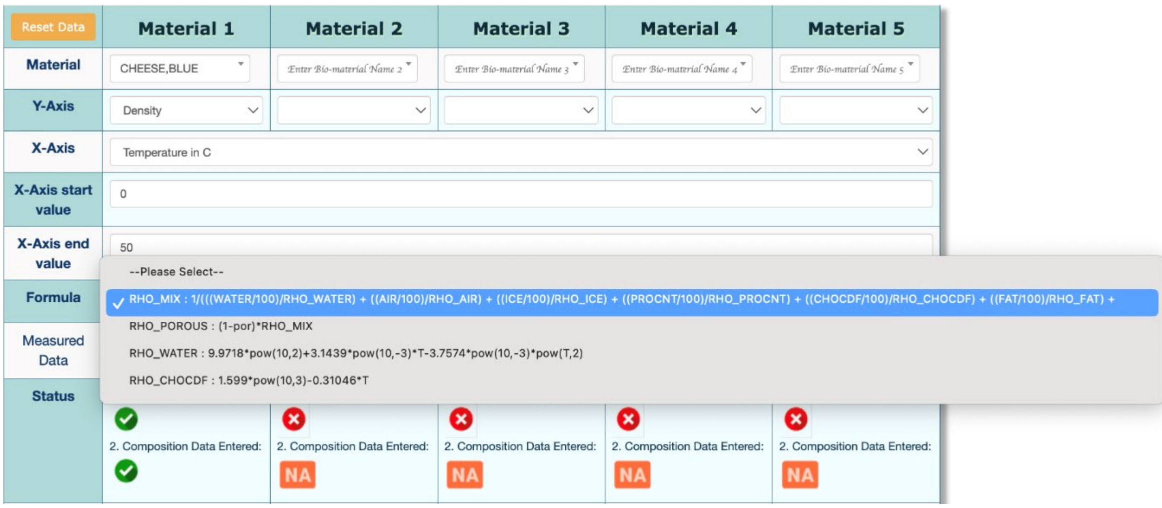


Step 4: Select "Chart Bio-Material Formula" to plot the material properties as shown below.



Multiple formulas appear under the 'Formula' tab when charting materials, which one should be used?

Many of the materials in this database and associated properties have multiple formulas associated with them that may be shown in the dropdown of the "Formula" tab in "Chart Property" Below is an example of a user trying to observe the change in density with temperature of Blue Cheese (1004), with the drop of formulas shown as well:



The user has choices between RHO_MIX, RHO_POROUS, RHO_WATER, and RHO_CHOCDF. When choosing a formula, the user must define the context and intention of charting this property for the given material and understand what each formula actually produces. The user may investigative the formula further by viewing details of the formula (**Section 1.3**).

In this example, RHO_MIX is used to calculate the mixed density of a material that is a mixture of various components, which would be useful for dealing with heterogenous materials, which would apply to most in the database. RHO_POROUS considers the porosity and mixed density and may be used for porous or highly permeable materials, like Swiss Cheese. RHO_WATER provides the density of water as a function of temperature. Lastly, RHO_CHOCDF should be used for materials with high carbohydrate content, which may be observed in the material components, shown below for Blue Cheese.

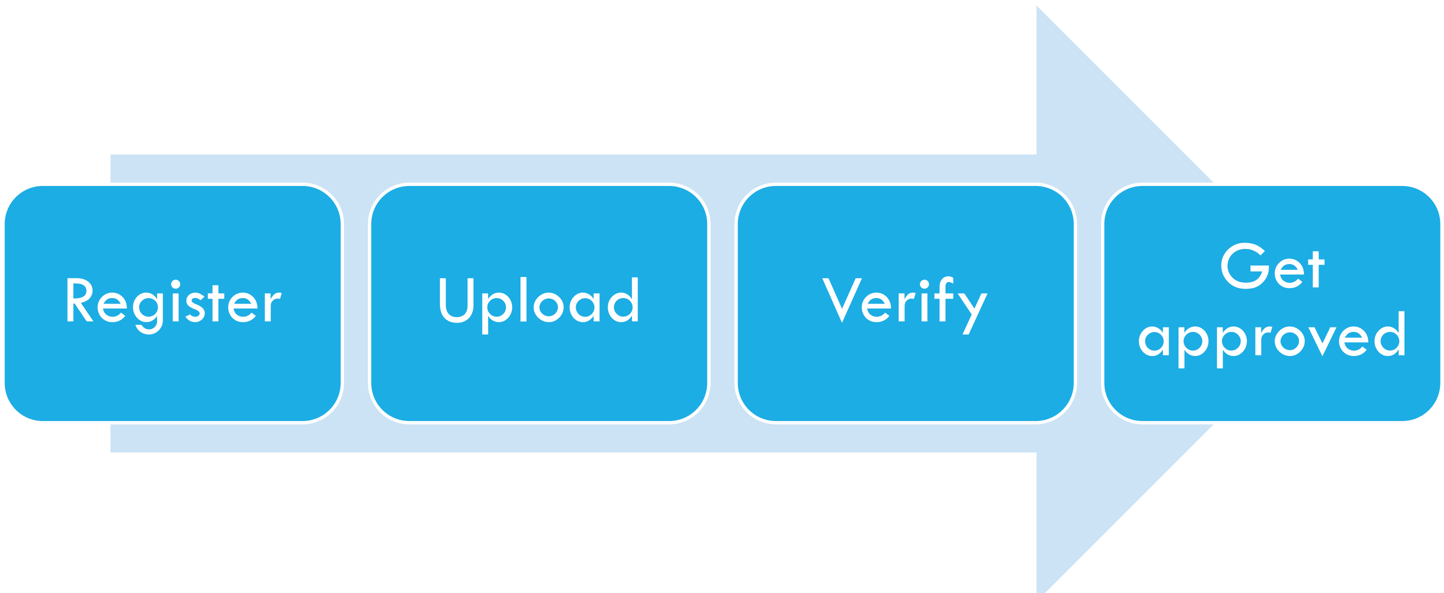
SECTION 3: DATA INPUT

This portion of the manual provides a comprehensive guide for users wishing to contribute their own findings or literature to this database and outlines step-by-step processes for users to get verified and understand the required standards for adding consistent and quality data. Encouraging users to share their data in a user-friendly interface will allow the database to grow and evolve organically as a collaborative space.

EVERYONE CAN ENTER DATA

1. Make your research data accessible to the world instantly.
    a. If you have measured data that you would like everyone to use, the fastest way to achieve it is to upload your data to this platform.
2. Anyone can enter data following the steps below.
3. Contact Ashim Datta at akd1@cornell.edu for more information.

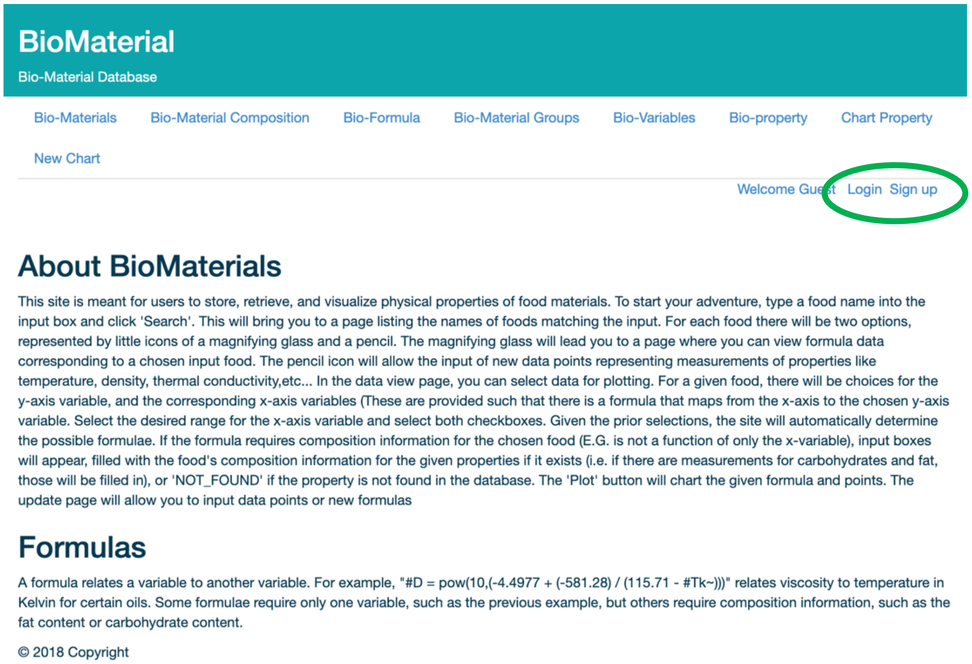
OVERVIEW OF STEPS



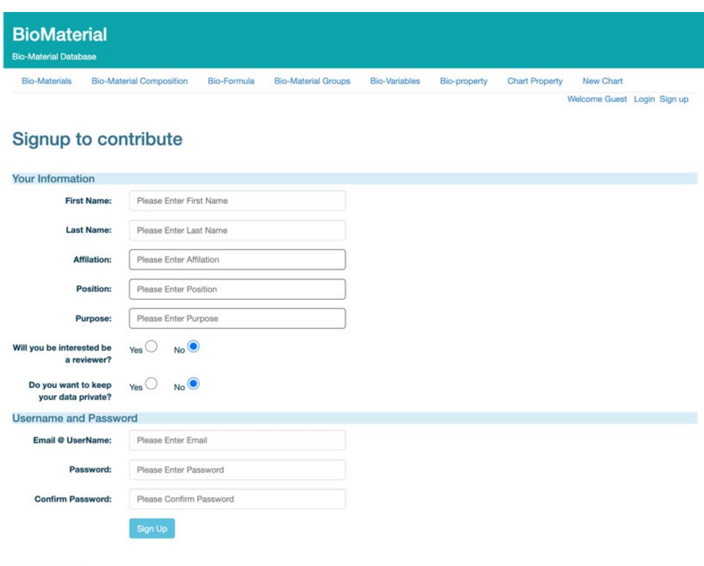
1. Isolating Data: Gather property data from reliable, trusted sources such as research papers, books, manual, and online sources. Understand the property and consider the source and relevance of data to ensure accuracy. Extract and transfer the isolated data and share for approval.
2. Entering Data: In the “Contribute Data” section of the database is where formulas may be added with the proper variable. More detail discussed on the next page.
3. Validation: Follow the steps outlined in Section 1 of Data Retrieval to obtain a plot of the newly entered data. Examine this plot to ensure data was entered correctly and is represented accurately.

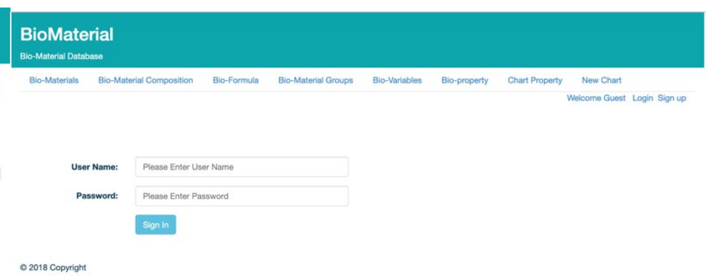
SECTION 3.1: GETTING VERIFIED

Step 1: In the database, users must login and get verified to enter data. Select “Sign Up” if unverified and enter the required fields. If verified, select “Login” and enter credentials.



Step 2: Selecting “Sign up” will take the user to the sign-up page below (left). Users selecting “Login” will take the users to the login page below (right). Users signing up will need approval before contributing data.



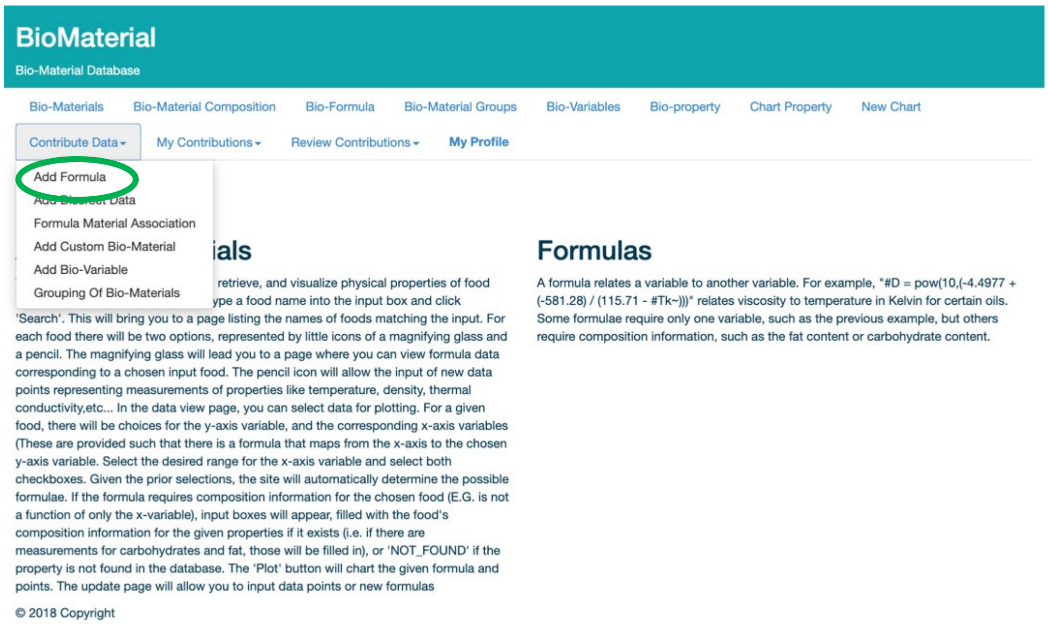


Step 3: Once verified, select the "Contribute Data" dropdown and choose the desired category of data to enter.

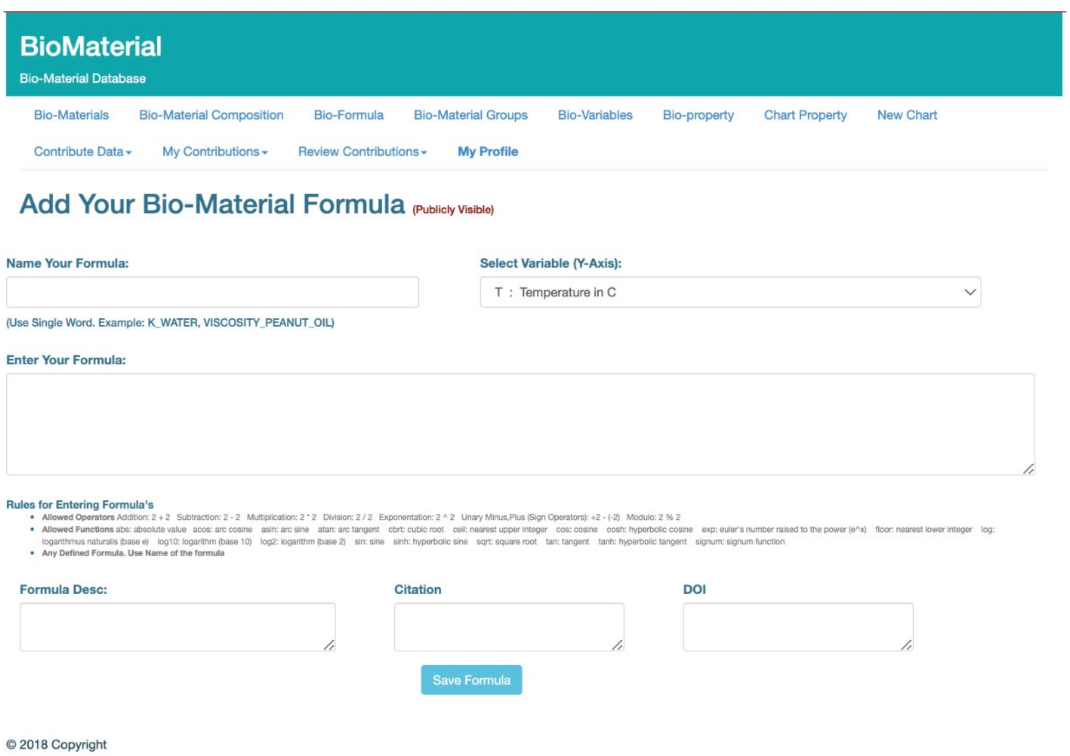
SECTION 3.2: ADDING FORMULAS

This section gives instruction for adding formulas that allows users to define relationship between various food properties. In this database, a variable represents a value that can change according to user input. In contrast, a parameter is constant value used in the formula that cannot change once defined. It is important to follow the proper format and structure when adding formulas to the database so that they may be used.

Step 1: In the dropdown menu shown in Section 1: Step 2, select "Add Formula".



Step 2: Fill out the fields (displayed below) according to the source.



Example Step 1: All formulas found must be cited by peer-reviewed literature. For example, the formula name C_P_SOL (ID: 182) is cited from Gulatti and Datta (2013). Then, an appropriate name must be added along with the formula added in proper format. The following excerpt is from Gulatti and Datta (2013):

12.1. Theoretical models

Specific heat is commonly estimated based on the mass fractions (x_i) of the individual components and their corresponding specific heats ($C_{p,i}$)

$$C_p = \sum_i x_i C_{p,i} \tag{64}$$

$$C_{p,w} = 4.1762 - 9.0862 \times 10^{-5} T + 5.4731 \times 10^{-6} T^2 \quad 0^\circ C \leqslant T < 150^\circ C \tag{68}$$

$$C_{p,w} = 4.0817 - 5.3062 \times 10^{-3} T + 9.9516 \times 10^{-4} T^2 \quad -40^\circ C < T < 0^\circ C \tag{69}$$

$$C_{p,prot} = 2.0082 + 1.2089 \times 10^{-3} T - 1.3129 \times 10^{-6} T^2 \tag{70}$$

$$C_{p,fat} = 1.9842 + 1.4733 \times 10^{-3} T - 4.8008 \times 10^{-6} T^2 \tag{71}$$

$$C_{p,carb} = 1.5488 + 1.9625 \times 10^{-3} T - 5.9399 \times 10^{-6} T^2 \tag{72}$$

$$C_{p,fiber} = 1.8459 + 1.8306 \times 10^{-3} T - 4.6509 \times 10^{-6} T^2 \tag{73}$$

$$C_{p,ash} = 1.0926 + 1.8896 \times 10^{-3} T - 3.6817 \times 10^{-6} T^2 \tag{74}$$

$$C_{p,ice} = 2.0623 + 6.0769 \times 10^{-3} T \tag{75}$$

$$C_{p,a} = 1.006 \tag{76}$$

Example Step 2: Combining the information found in this paper, a formula that combines these concepts to express the overall specific heat of dry food solids based on their composition made be inputted:

Bio-Formula Details

×

ID	182
Name	C_P_SOL
Formula	((PROCNT/100)*C_P_PROCNT+(FAT/100)*C_P_FAT+((CHOCDF-FIBTG)/100)*C_P_CHOCDF+(FIBTG/100)*C_P_FIBTG+(ASH/100)*C_P_ASH)
Y-axis Variable	c_w - Specific Heat
Variable ID	10027
Formula Desc	Specific heat of dry solids
Citation	Gulatti and Datta (2013)
DOI	
Approved	0
Added by	test
Last Updated By	test
Initially Created at	2020-10-13 18:03:38.0
Last Upadted at	2020-10-13 18:03:38.0

Example Step 3: Notice the convention of the inputted fields in the previous step. Additionally, once a formula is created, it may be called in a different formula, as these build on each other (highlighted below). It's important that the lower level formulas are inputted before higher levels (in this case, the lower level formula is C_P_SOL):

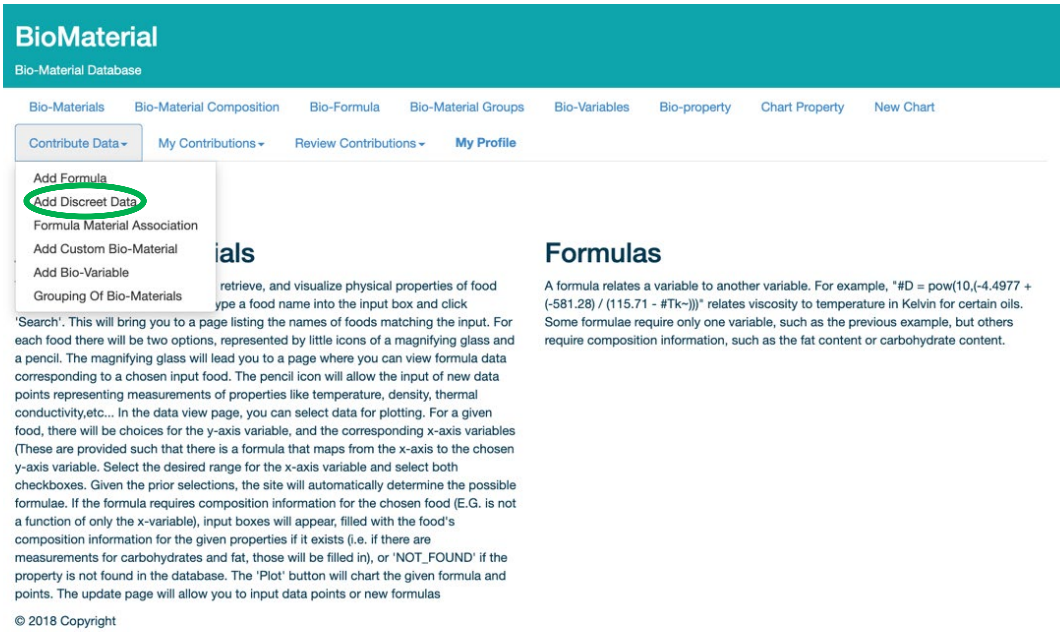
Bio-Formula Details

ID	183
Name	C_P_FROZMIX
Formula	(WATER/100)*((1-ICE/100)*(C_PICE_OKOS)+(ICE/100)*C_PICE_OKOS+FUS_ICE_*(((dICE)/100)/(dT)))+(1-WATER/100)*C_P_SOL
Y-axis Variable	c_w - Specific Heat
Variable ID	10027
Formula Desc	Specific heat of a frozen composite
Citation	Datta and Rakesh (2009)
DOI	
Approved	0
Added by	test
Last Updated By	test
Initially Created at	2020-10-13 18:14:34.0
Last Upadted at	2020-10-15 17:48:34.0

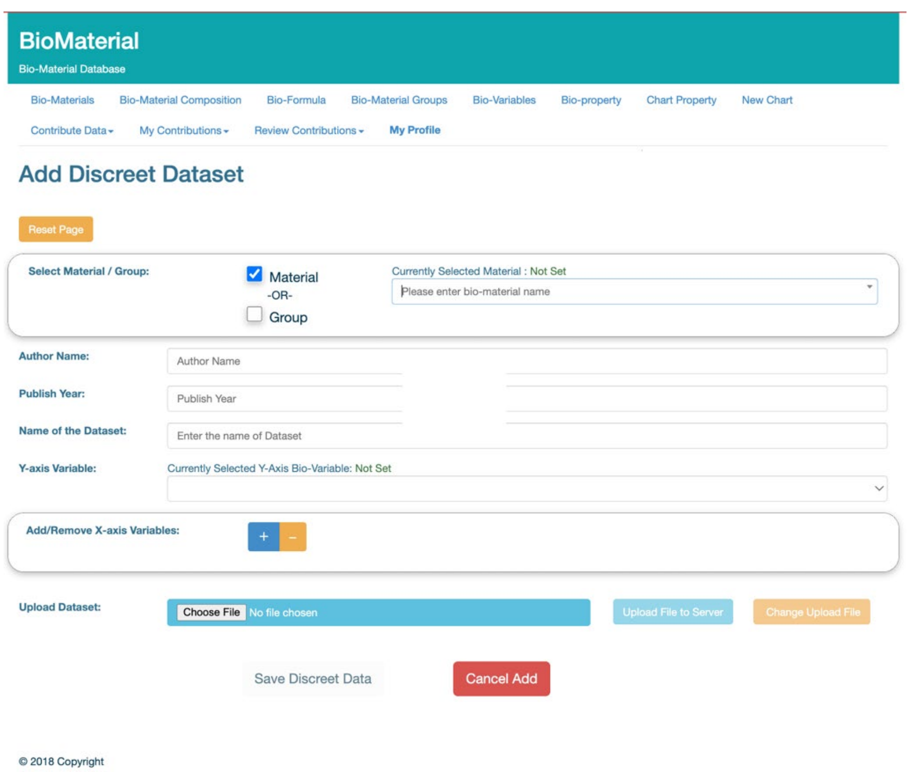
SECTION 3.3: ADDING DISCRETE DATA

Discrete data refers to the distinct and separate values that can be counted, with clear boundaries between each value. Different from continuous data, which can take any value in a range, discrete data is countable and finite. Users may input discrete datasets that involve specific, individual measurements related to each biomaterial with proper citing. This allows for precise modeling and predictions that use the formulas from the previous section.

Step 1: In the dropdown menu shown in Section 1: Step 2, select "Add Discreet Data".



Step 2: Select a material or group to add a data set and fill out the required fields.



SECTION 3.3.1: EXRACTING DATA FROM FIGURES

Reviewed and approved inputs of discrete data may be viewed following steps of Section 6, Data Retrieval (Bio-properties). These values are specifically measured, recorded, and should be properly cited. Note the correct Y-axis Variable and X-axis Variables to be added. Multiple X-axis Variables may be added. Here is a step-by-step example of taking raw data from a figure and uploading it to the database.

Example Step 1: Obtain the raw data from the selected paper, an example displaying the permeability of raw potato tissue is shown below (Datta, 2006).

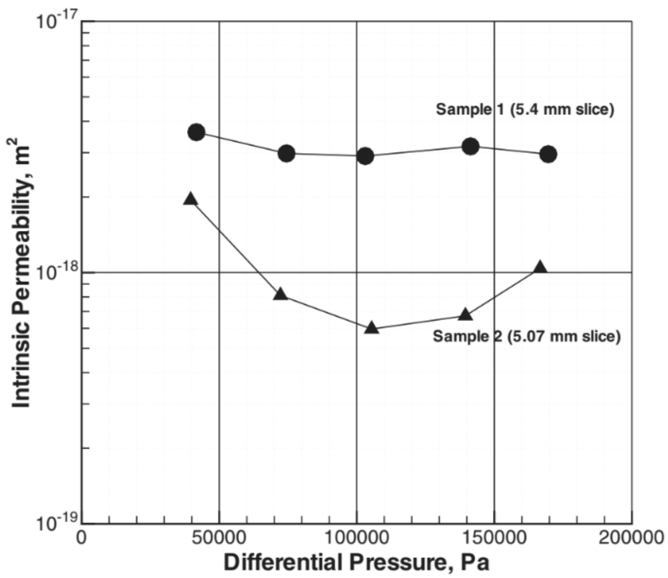
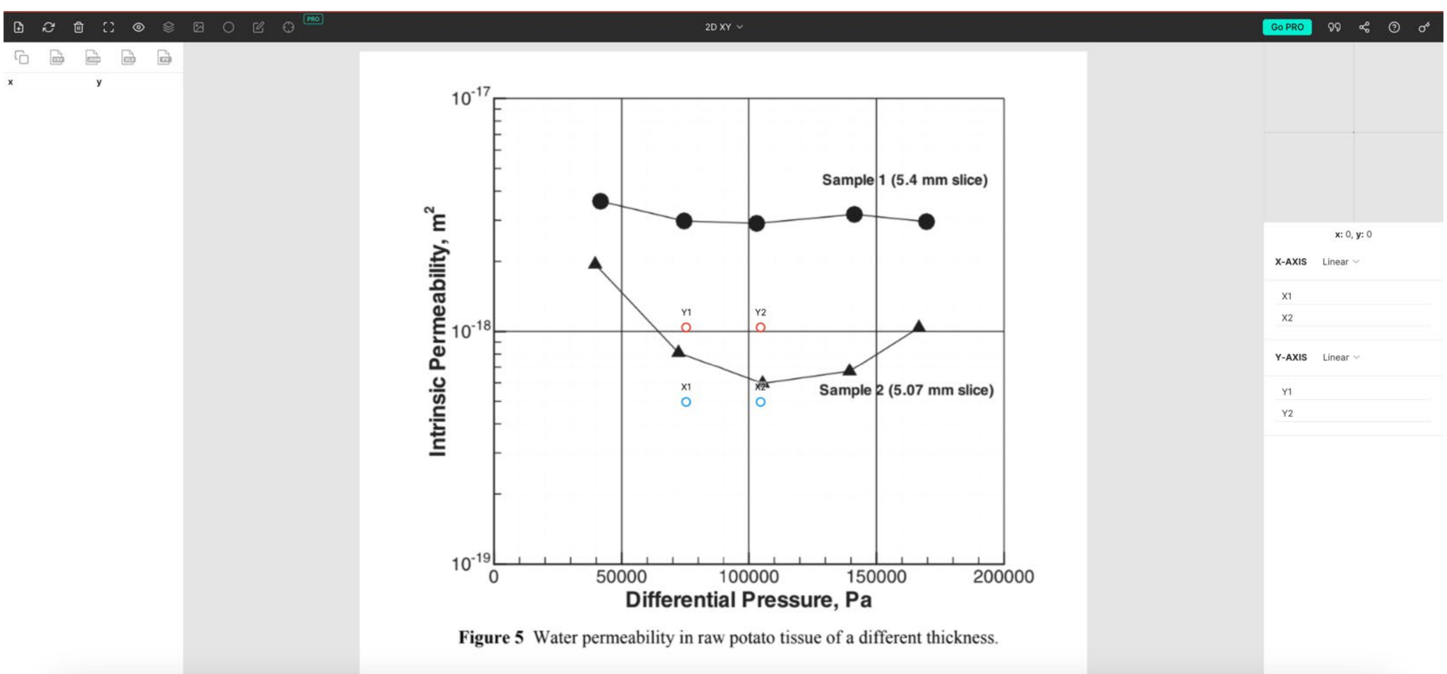


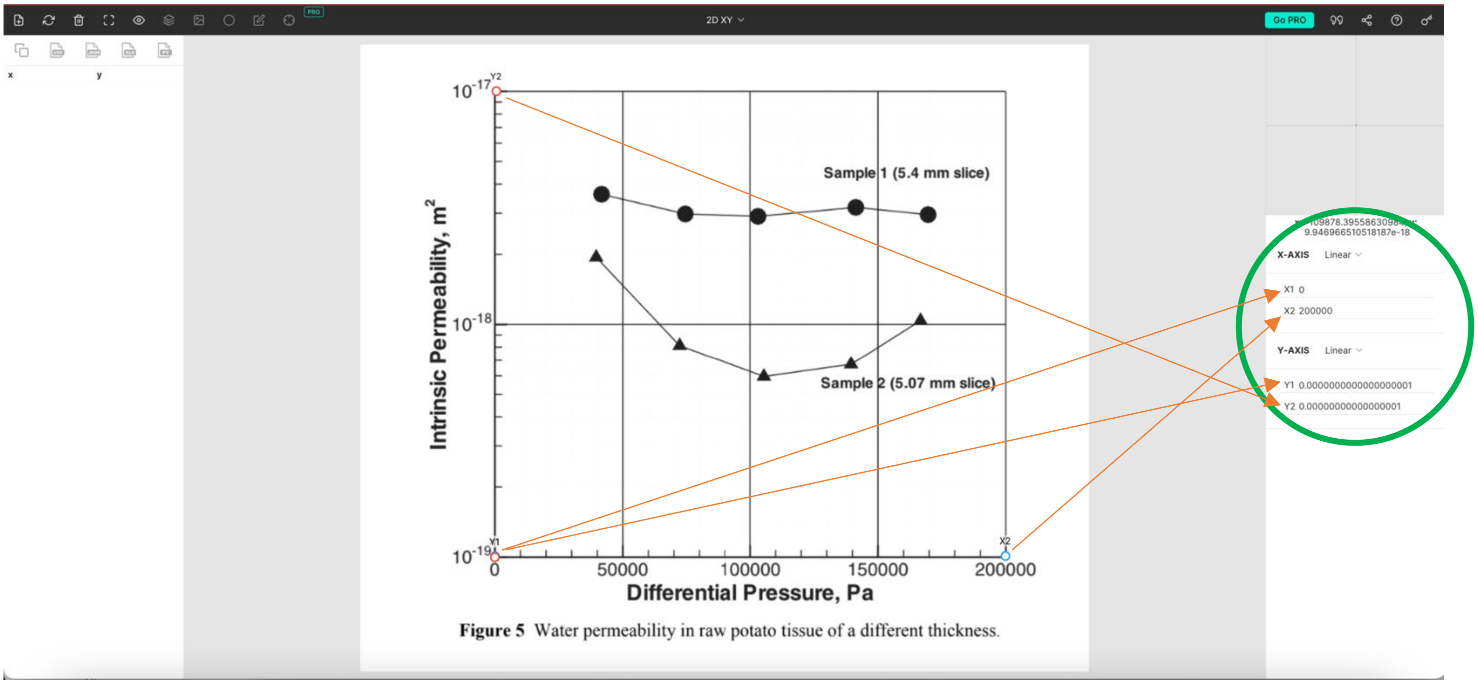
Figure 5 Water permeability in raw potato tissue of a different thickness.

Example Step 2: If the numerical data is not given, users may obtain this from figures through https://plotdigitizer.com/app. Upload the figure (this may be done in the browser).

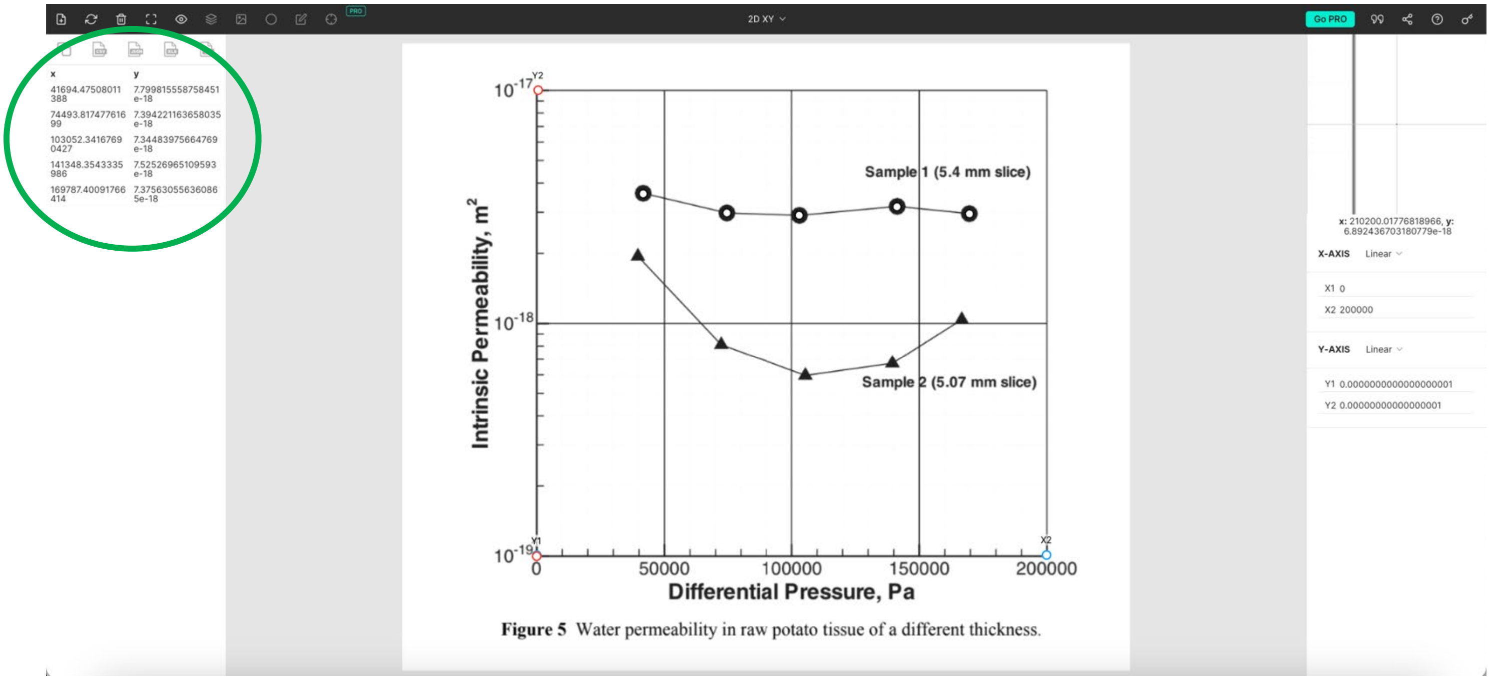


Example Step 3: Define the axis by placing the X1, X2, Y1, and Y2 circles over the coordinates. Manually enter these X and Y axis values in the panel on right (circled below).

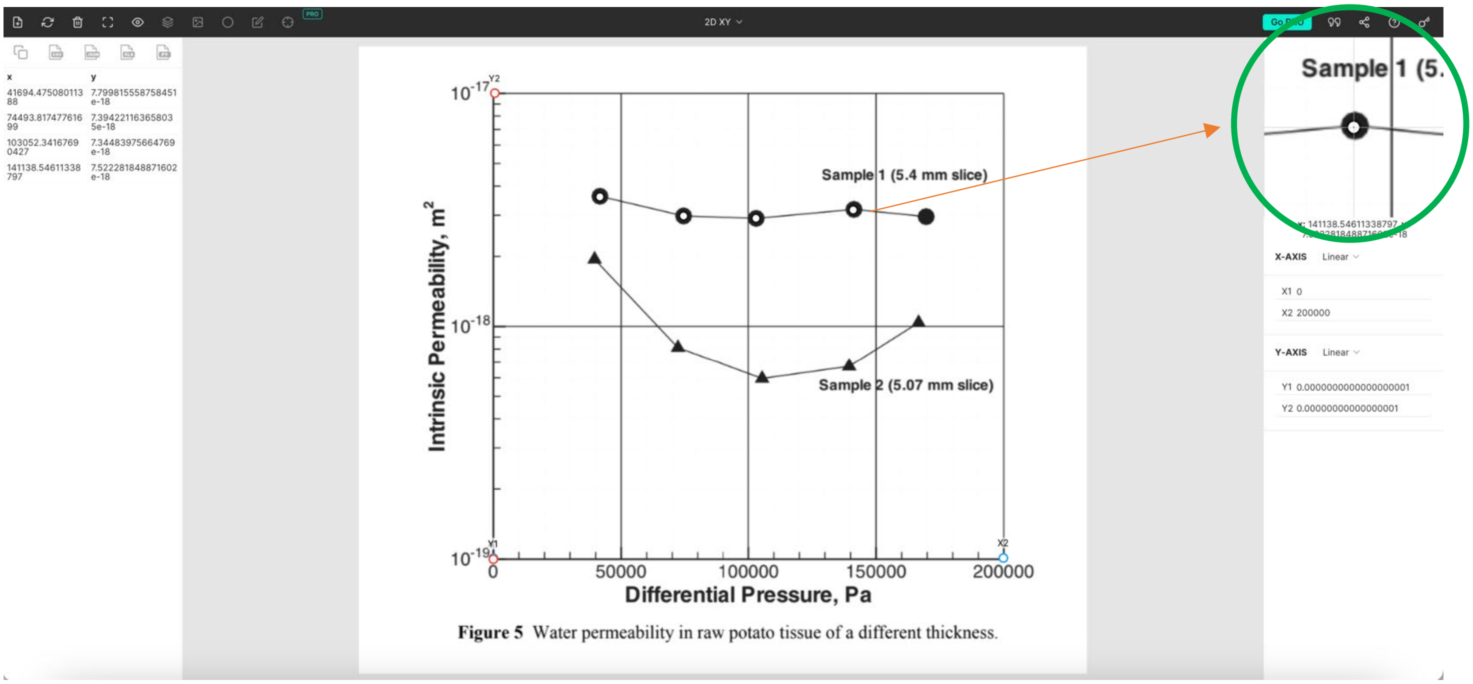
Note: If axial values are in scientific notation, they must be expressed in standard notation in this software. For example, '10^-17' becomes '0.00000000000000001'.



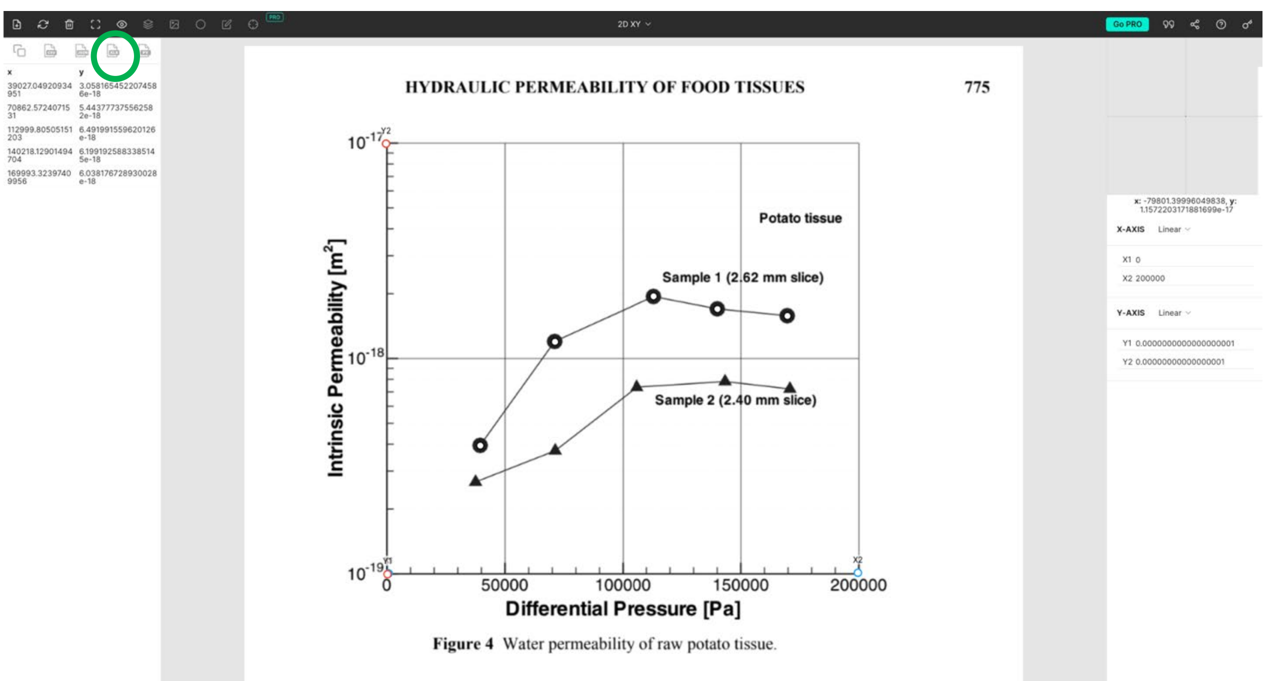
Example Step 4: To digitize these data points, click to add a data point and drag it to align it with the figure. Here, five data points (in white) are added and overlapped on the circle-shaped points (in black) to complete the permeability dataset for 2.62 mm slice potatoes.



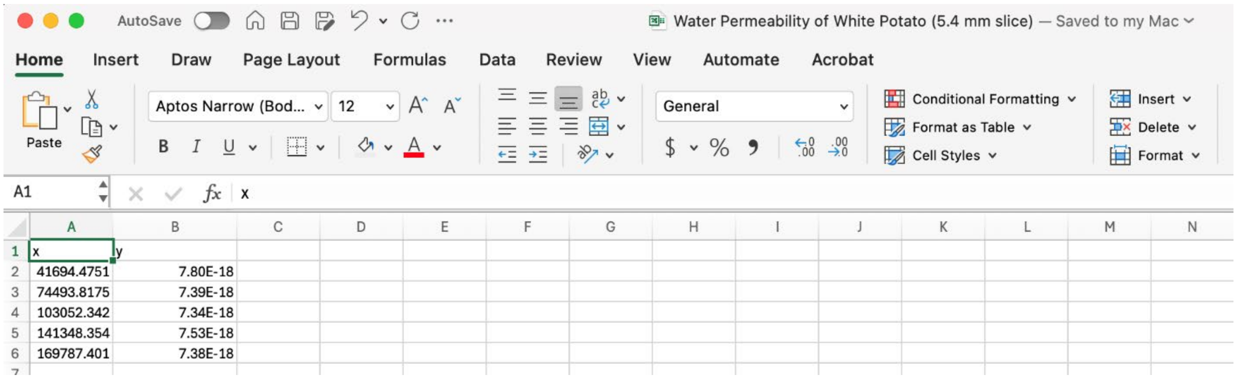
Helpful Tip: Use the magnified window in the top right for accurate placement of data points.



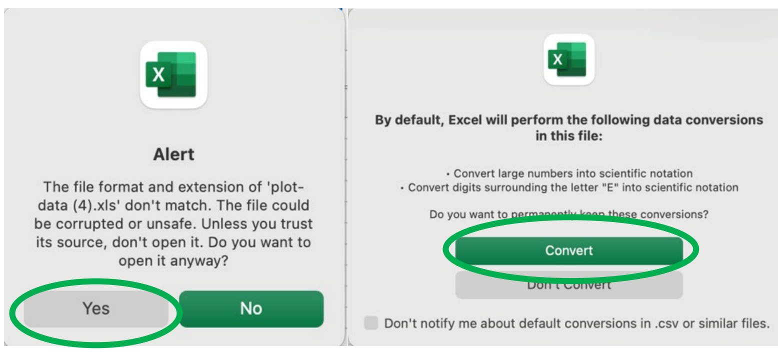
Example Step 5: Lastly, export this data such that it may be uploaded to the database. Ensure all corrections to the dataset are made and that the variables and units are appropriate. Export as an .xls file. For figures with two sets of data, move each data point to the next set and re-export the data, changing the name to reflect the new dataset.



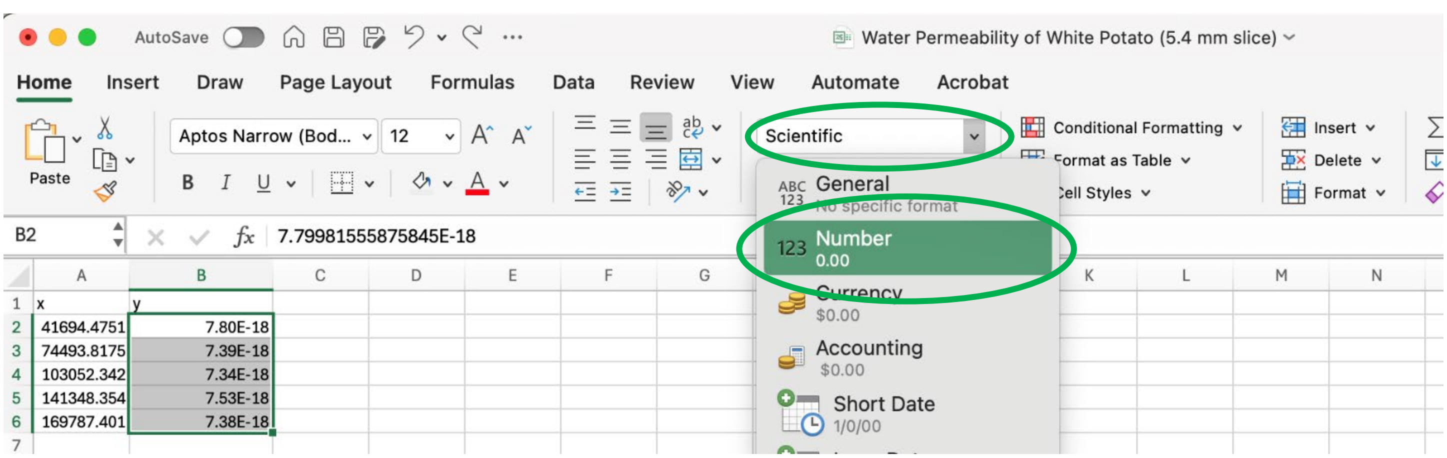
Example Step 6: Below is the exported format from PlotDigitizer. **If no values are in scientific notation, please see Example Step 10**.



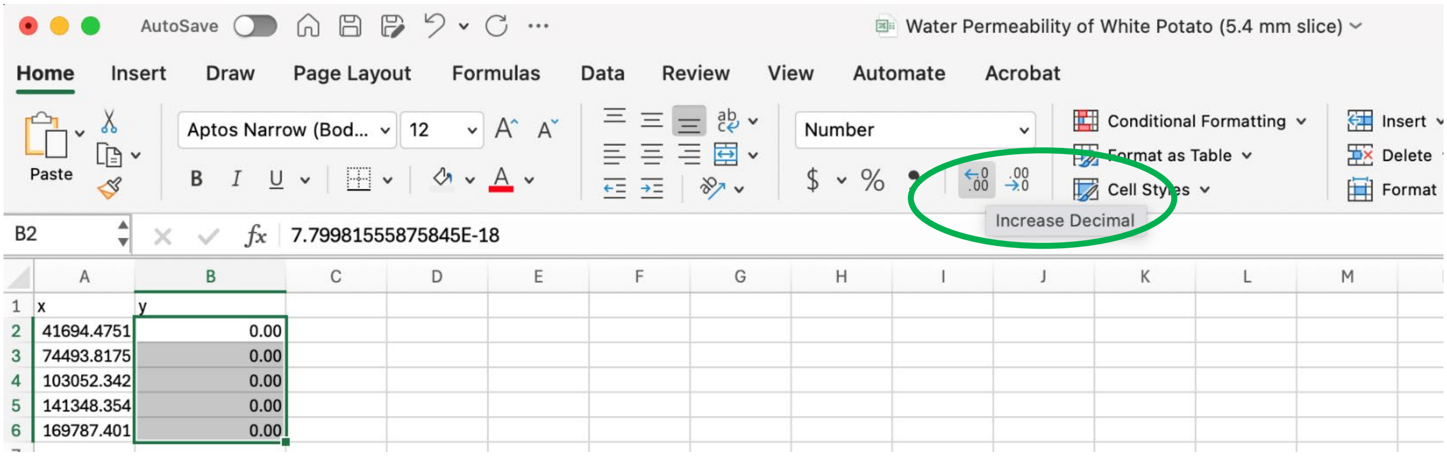
Note: All values must align with the units of each variable in the database. Follow Section 1.5 to retrieve information and units of measurements for each variable. Here, *Differential Pressure* is measured in Pascals [Pa] and *Intrinsic Permeability* is measured in square meters [m^2]. Rename the file appropriately. <u>If prompted with a security warning, open anyway. Select 'Convert' if prompted.</u>



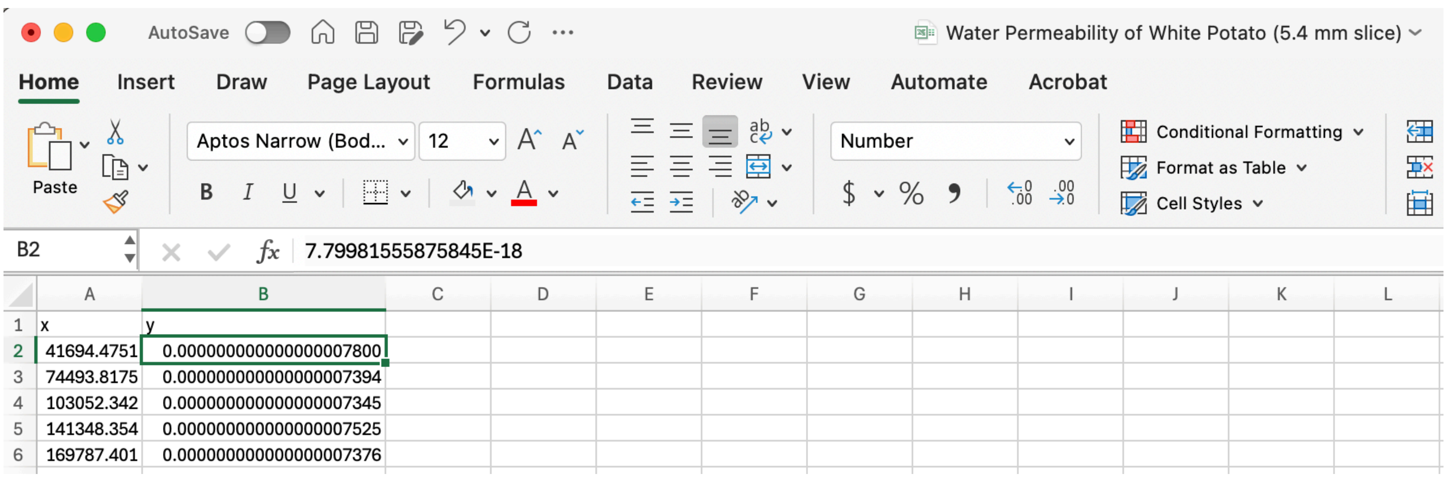
Example Step 7: Convert the values of scientific notation to standard notation by highlighting the numbers and selecting "Number" from the dropdown shown below.



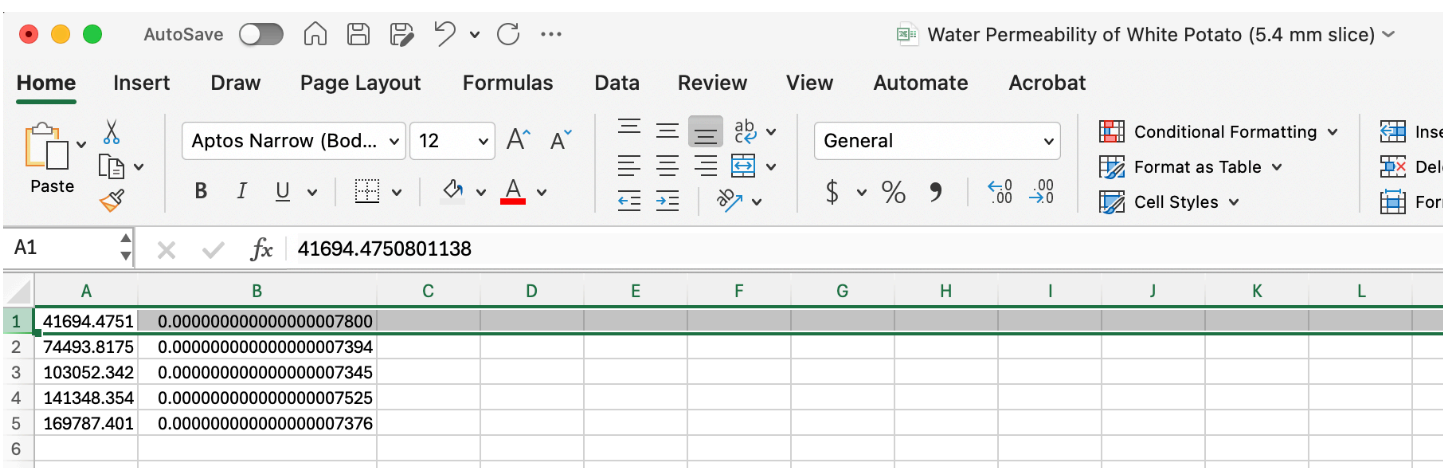
Example Step 8: For small values, this data may show up as 0.00. Highlight the column and select "Increase Decimal" (circled below) and click for as many times until non-zero values appear. Select for a few more times depending on the accuracy of the instrument from the source. Here, the permeability measurement is precise to two decimal places (for 10E-19 m^2), and is therefore good to the 10E-21 decimal place.



Example Step 9: Expand the column width to view all the values, if needed.

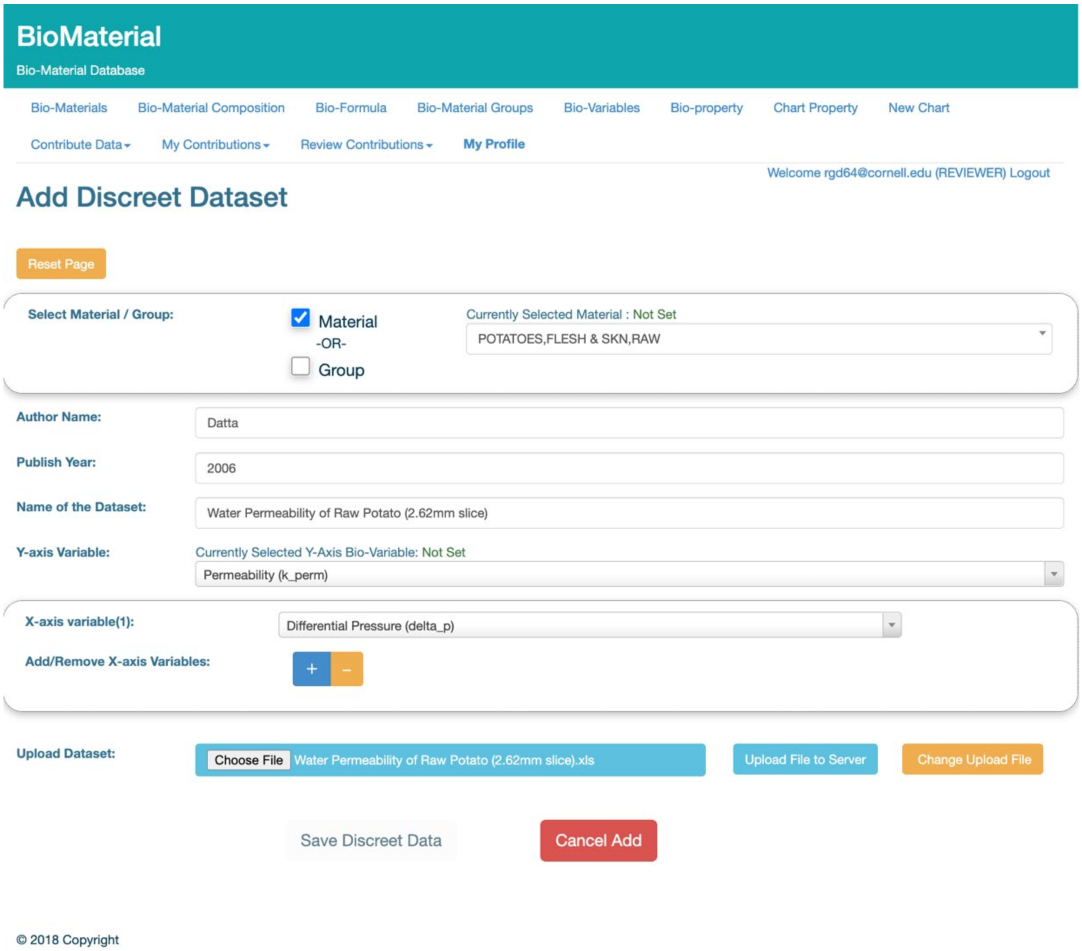


Example Step 10: Delete Row 1 of this table to ensure all values in the spread sheet are numerical values extracted from the source. **Below is the proper format that may be saved and exported to the database.**



******Fix error in formatting, unable to upload data********

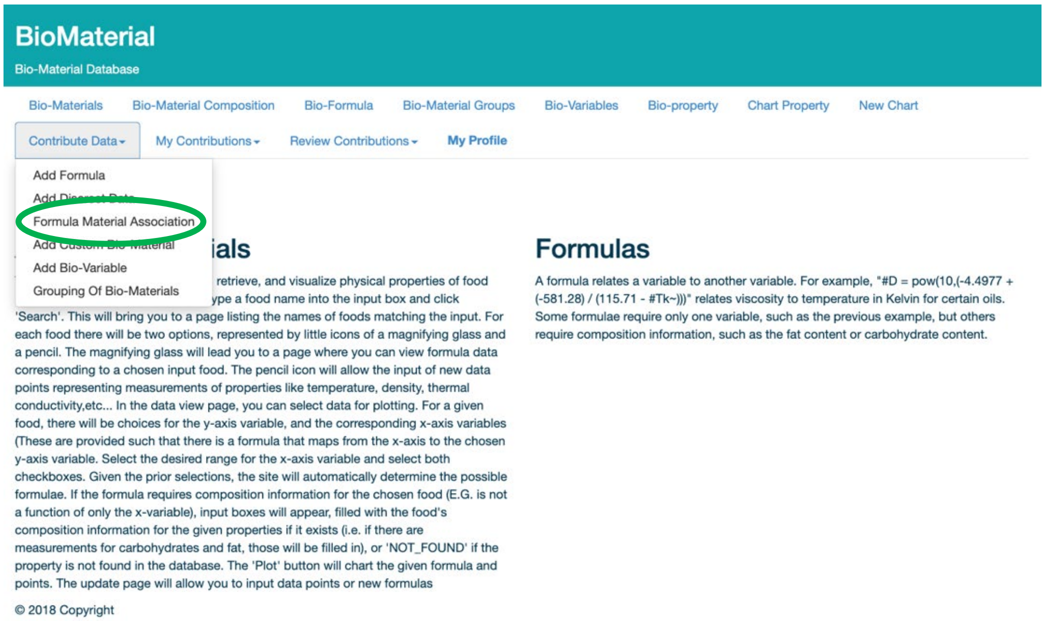
Example Step 11: Following Steps 1 & 2 of this section, users may now enter their data with their updated spreadsheet. Begin by selecting "Material" and determining the material that will be used. Here, raw potatoes (ID: 11352) will be used at the White Potatoes used in the paper. The following fields are to be filled out appropriately, and the x and y variable must resemble those extracted from the paper. Ensure the description is an accurate reflection of the data, and that the file is in a .xls format in order to be uploaded.



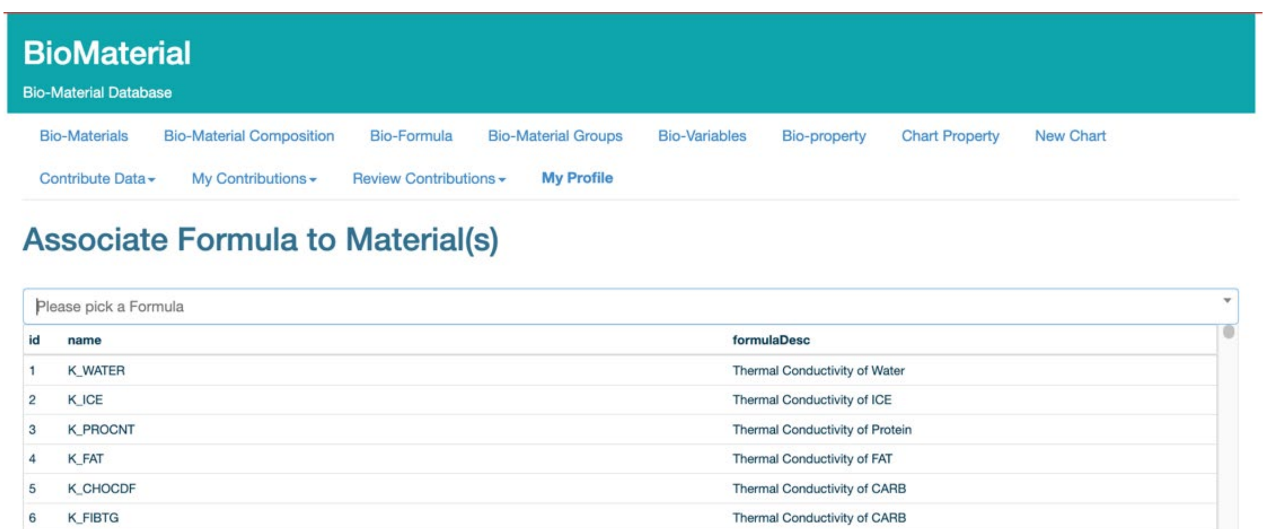
SECTION 3.4: FORMULA MATERIAL ASSOCIATION

Once a material and formula are entered from the steps in Section 2 and 3 of this portion, they must be associated. Grouping is an important aspect of this database, as it contributes to enhancing the input and prediction process. Grouping should be broad enough to encompass items with similar characteristics, while still ensuring accuracy. For example, it is appropriate to group the formulas within specific types of food, like russet, red, and sweet potatoes sharing similar properties. But grouping a formula for potatoes with carrots or other vegetables may be too broad and inaccurate due to different moisture contents, textures, and heating and cooling behavior, as well as other properties.

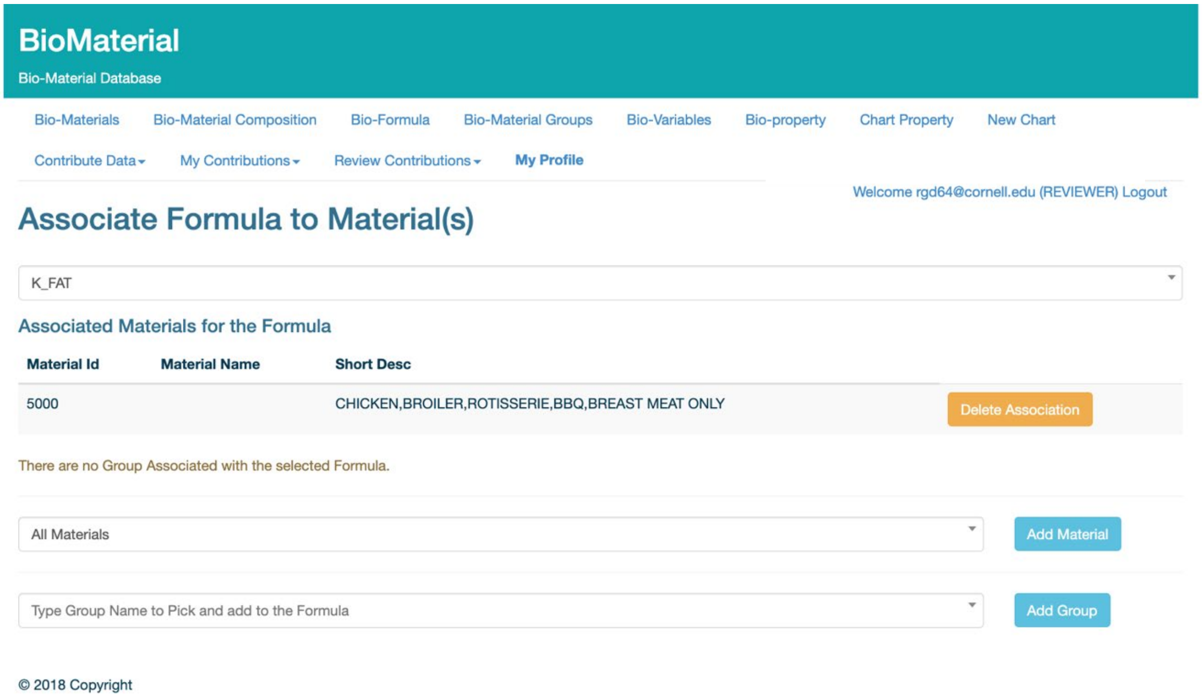
Step 1: In the dropdown menu shown in Section 1: Step 2, select "Formula Material Association".



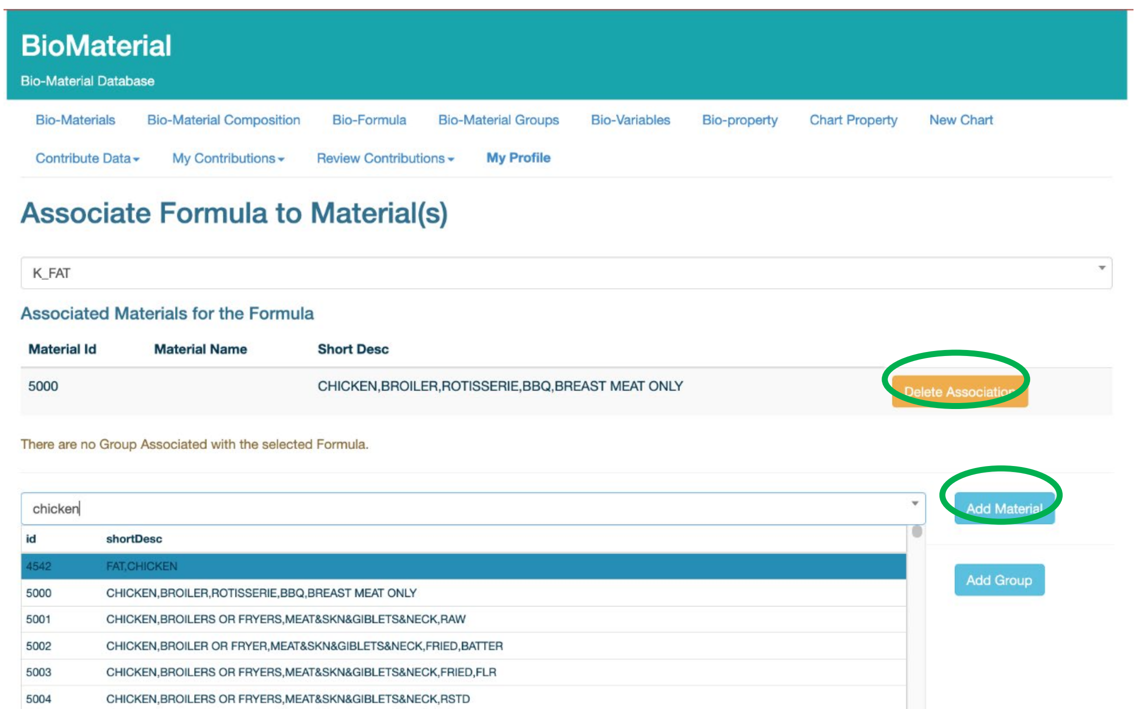
Step 2: Begin typing an existing formula or select from the dropdown. Please allow time for the dropdown to update if the formula is being typed. Descriptions of each are in the rightmost column.



Step 3: Once selected, associated materials and groups will appear below. Some formulas may have some or none.



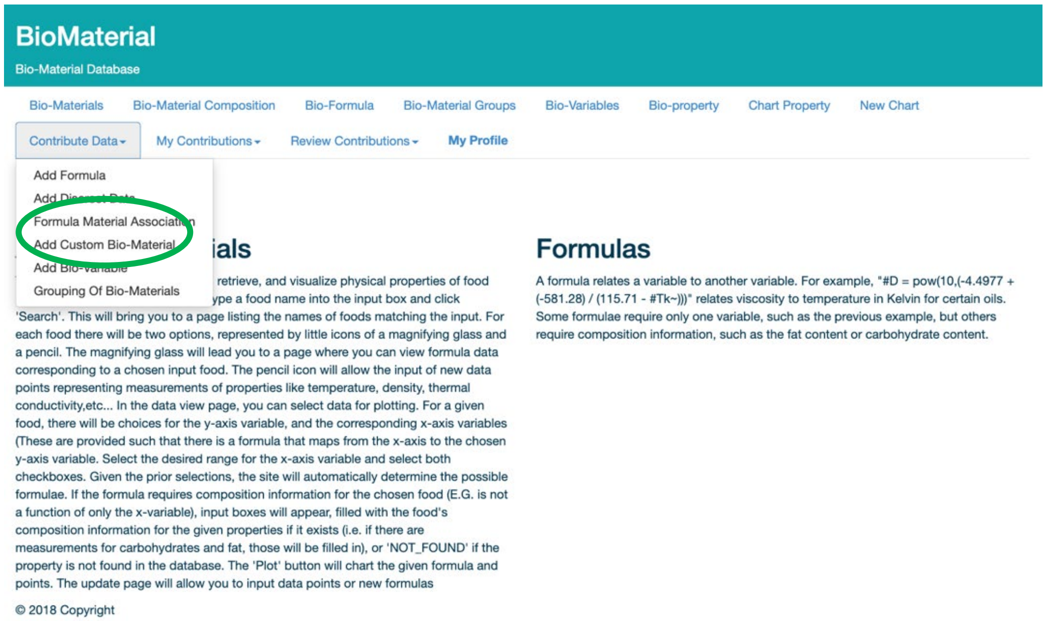
Step 4: Select the material from the dropdown and select "Add Material" to associate that material with the formula. Additionally, materials may disassociated from formulas by selecting "Delete Association".



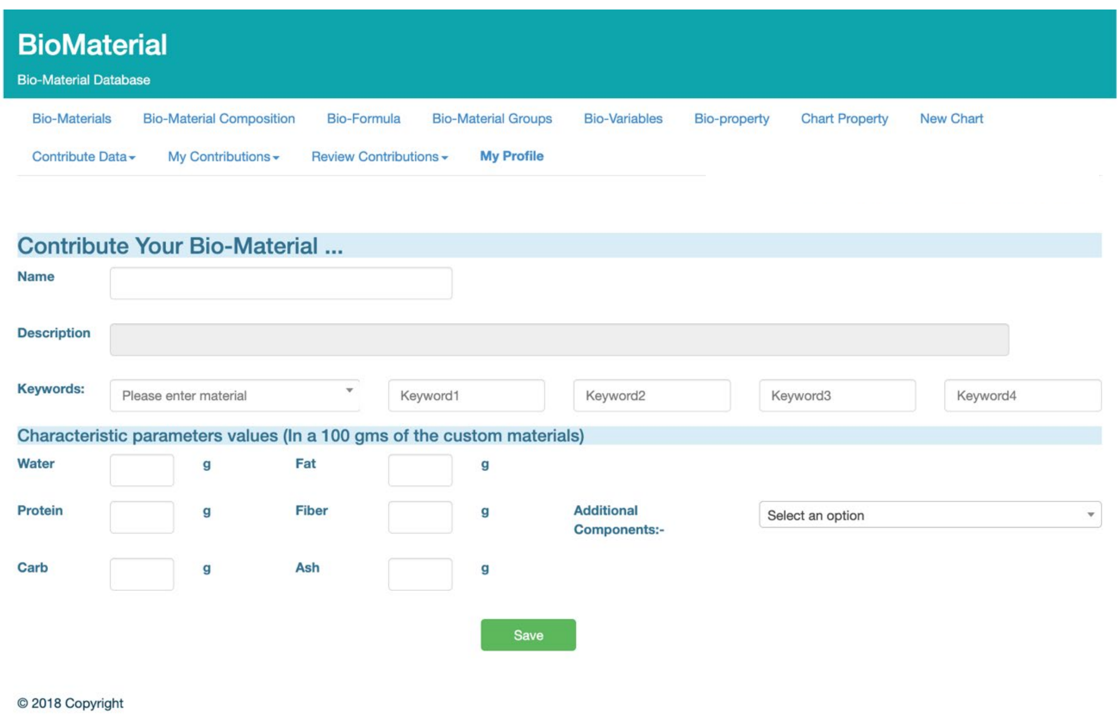
SECTION 3.5: ADD CUSTOM BIO-MATERIAL

This feature allows for users to add their own custom biomaterial data into this database. Users input detailed information in the fields displayed below that include descriptions, keywords, and characteristic parameter values. This feature enables enrichment of the database to include diverse and specific materials to foster collaboration among users from backgrounds in research, industry, and more.

Step 1: In the dropdown menu shown in Section 1: Step 2, select "Add Custom Bio-Material".



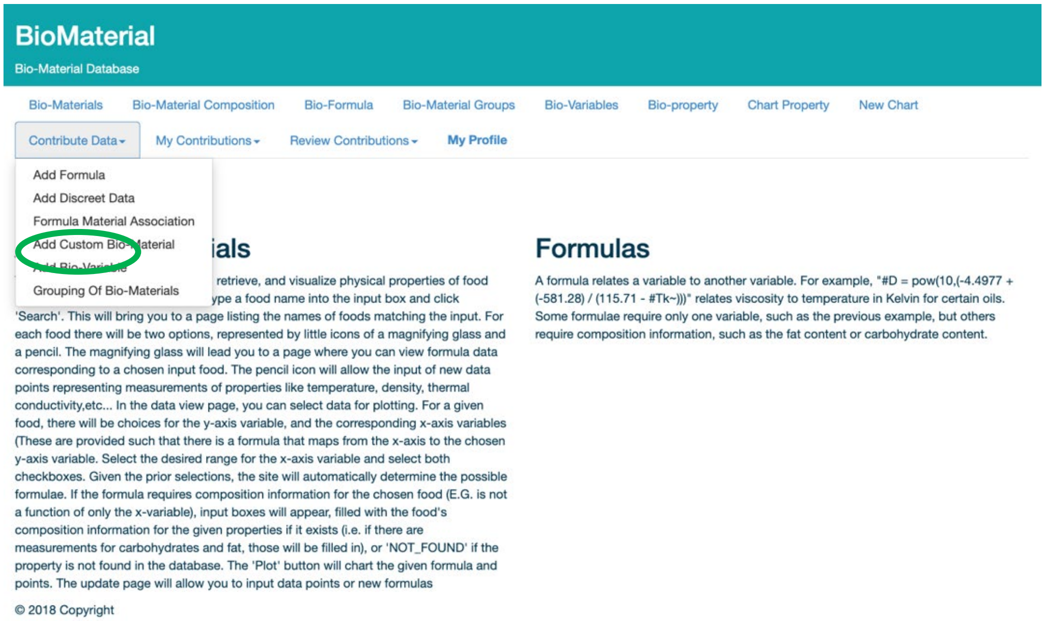
Step 2: Fill out the following fields. Ensure correct units in character parameter values.



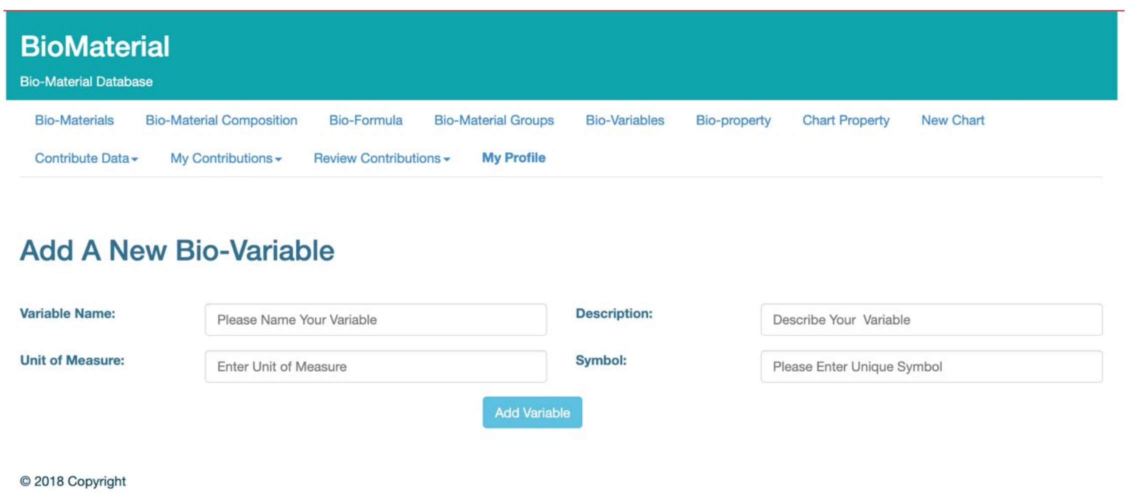
SECTION 3.6: ADD BIO-VARIABLE

This feature allows users to contribute to new variables in the database to enhance applicability. Users can define the variable and provide a description and other details. This function is crucial for capturing diverse properties of biomaterials to facilitate a more comprehensive research and development. User ability to add variables ensures the database remains extensive and up to date.

Step 1: In the dropdown menu shown in Section 1: Step 2, select "Add Bio-Variable".

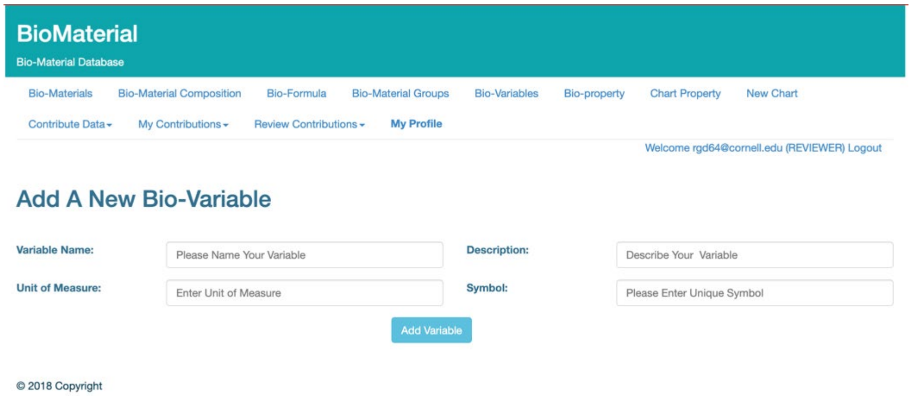


Step 2: Fill out the following fields.

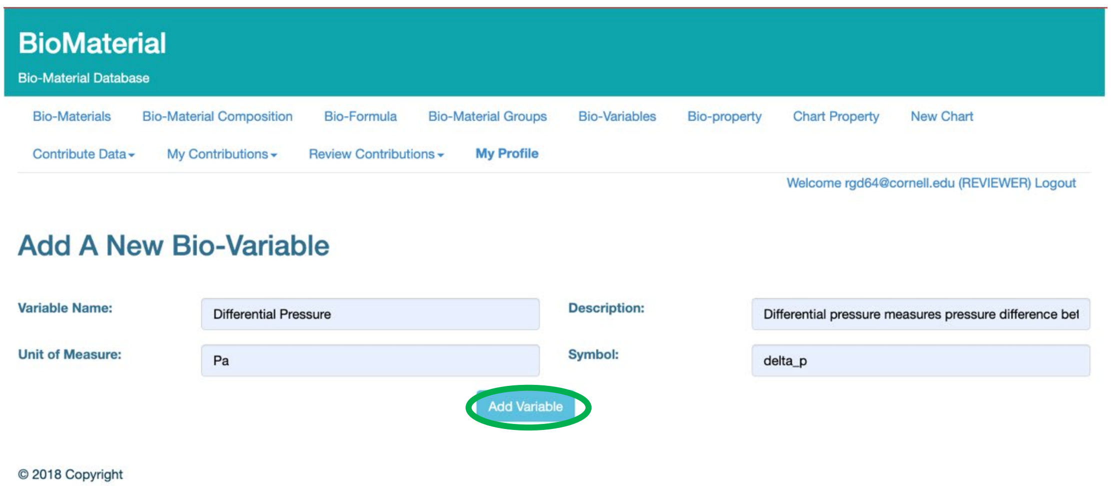


Helpful Tip: If adding a biomaterial that may be similar to one cataloged in the database, view the cataloged variable first to ensure proper and consistent formatting of newly entered biomaterial.

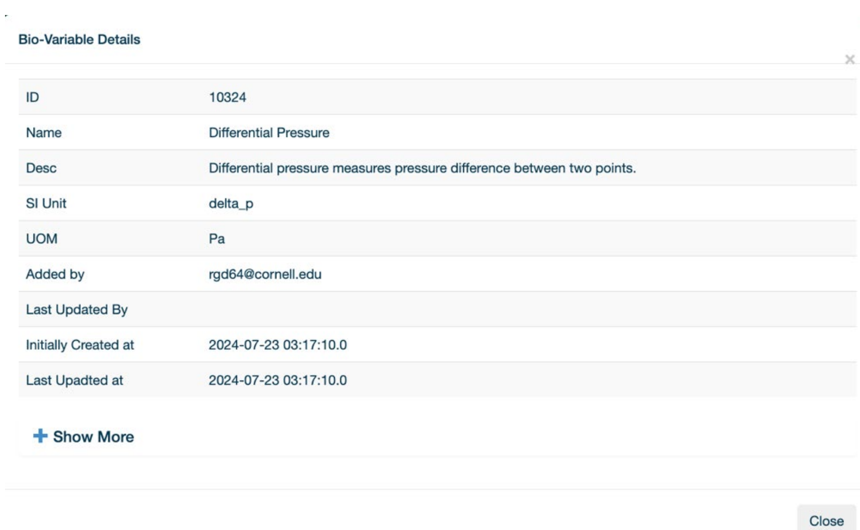
Example Step 1: Following Steps 1 & 2 of this section, users will be able to establish a new variable.



Example Step 2: The following fields are filled out for the new variable, *Differential Pressure*. Unit of measurements should be chosen based on common values given in literature and brief description should be added. A unique symbol should be relevant to the variable name. See below.



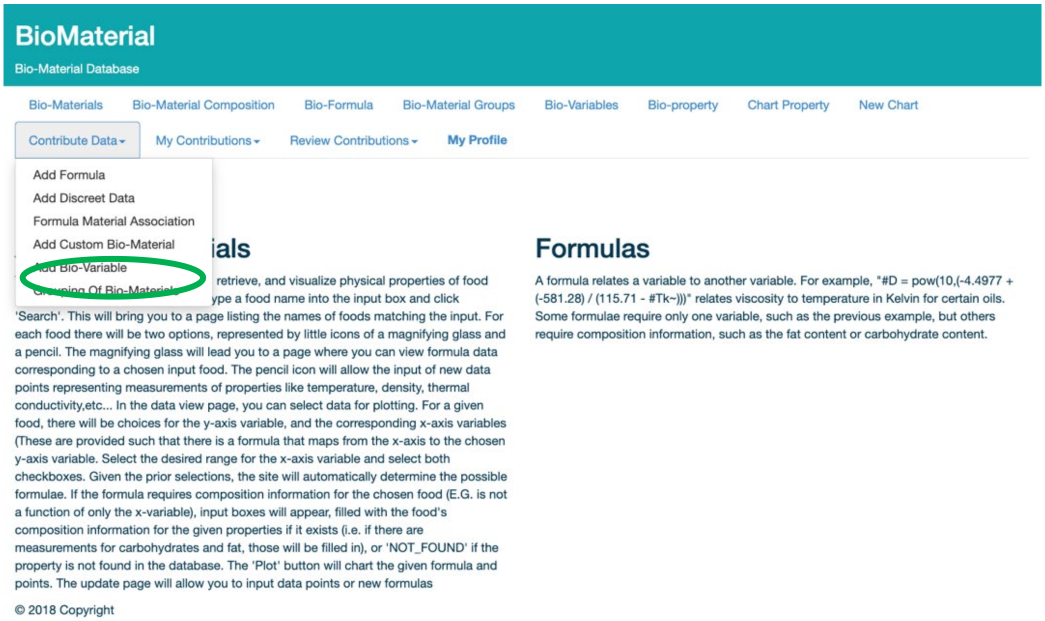
Example Step 3: Select "Add Variable" (circled above) to add the variable. Below is the result, viewed from the "My Contributions" tab.



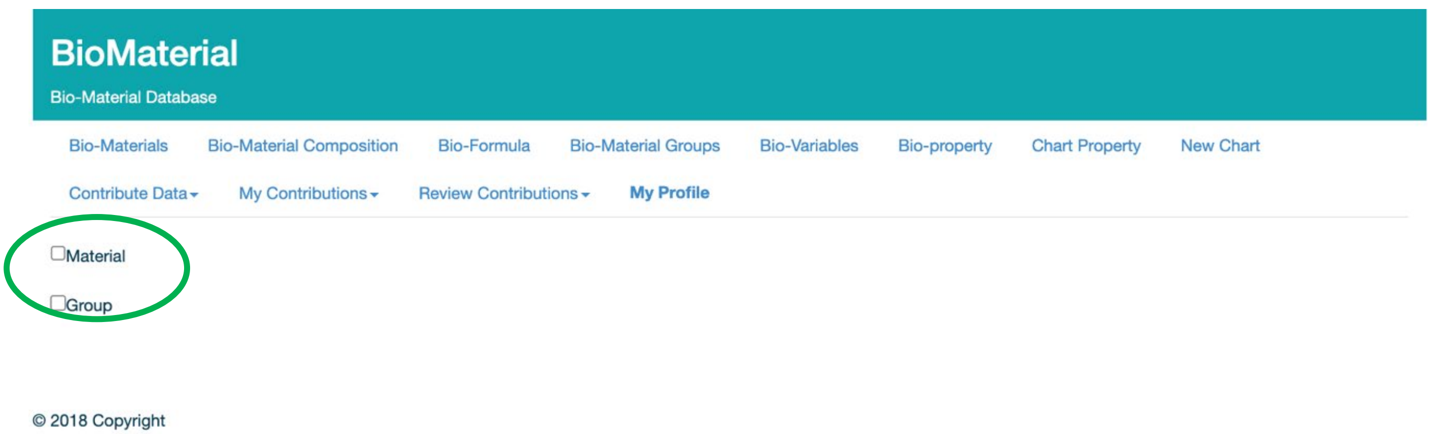
SECTION 3.7: GROUPING OF BIO-MATERIALS

This section allows users to group various biomaterials to their respective groups.

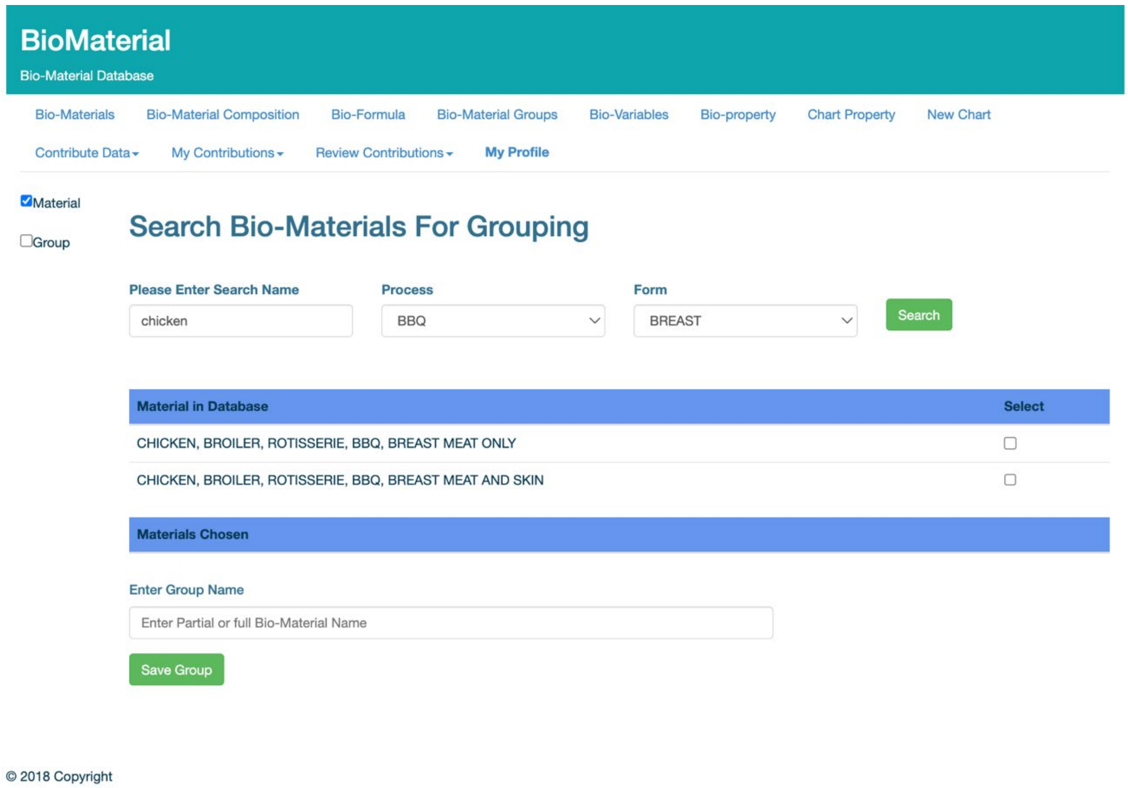
Step 1: In the dropdown menu shown in Section 1: Step 2, select "Grouping Of Bio-Materials".



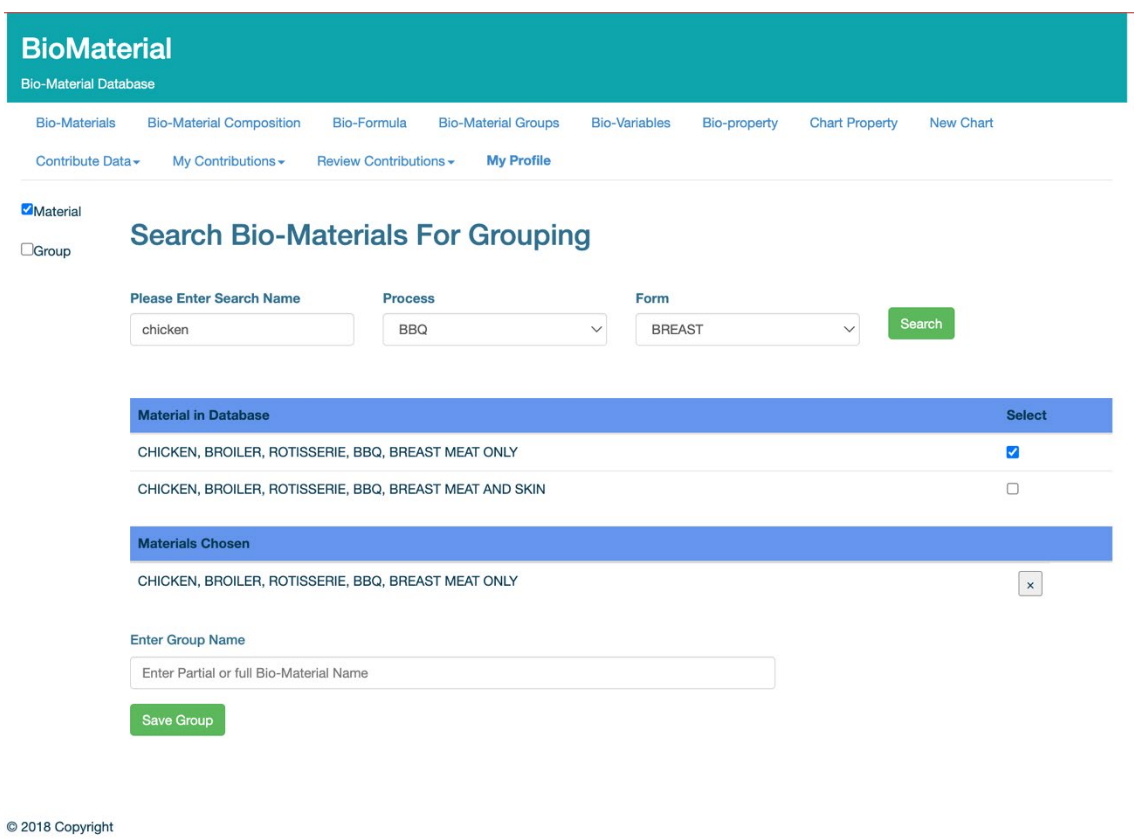
Step 2: Select the box for either "Material" or "Group".



Step 3a: If "Material" was selected, enter the name of the material along with the process and form. Select "Search" once these fields are complete.



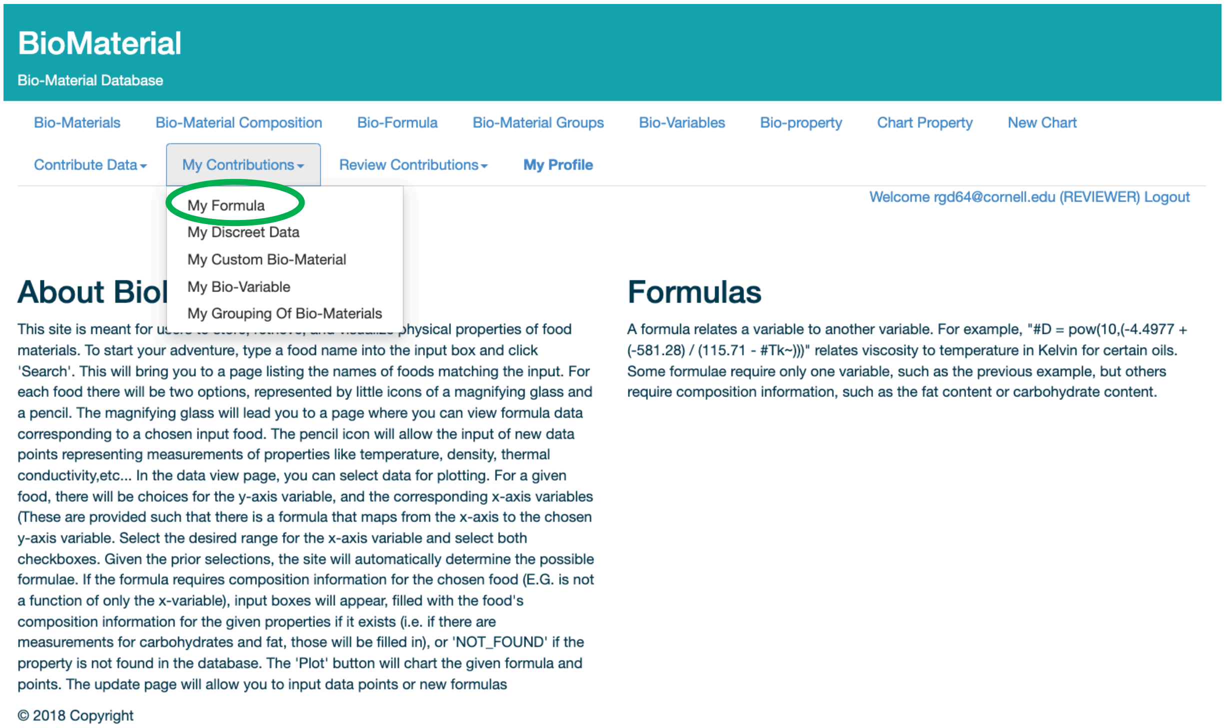
Step 4a: Select the material in the database, then type the group name to save this material to the group.



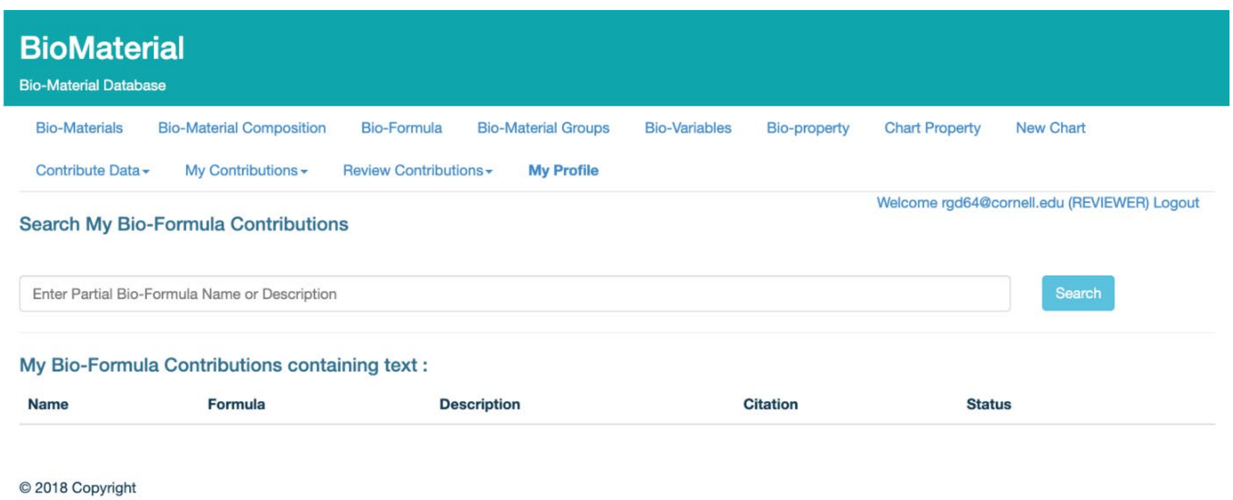
Step 3b: If “Group” was selected, type the name of the material and select “Search”. Select one of the given materials.

SECTION 3.8: MY CONTRIBUTIONS

Step 1: To review all contributions inputted by the user, select “My Contributions” dropdown.



Step 2: Select the option of Data Input to be viewed. This will take the user to a page displaying all contributed data of that category.



SECTION 3.9: TIPS ON DATA INPUT

For accurate data input in this biomaterials database, ensuring that all measurements are consistently formatted is crucial. In this section, various tips and short guides are provided to help users get a better sense of their data input.

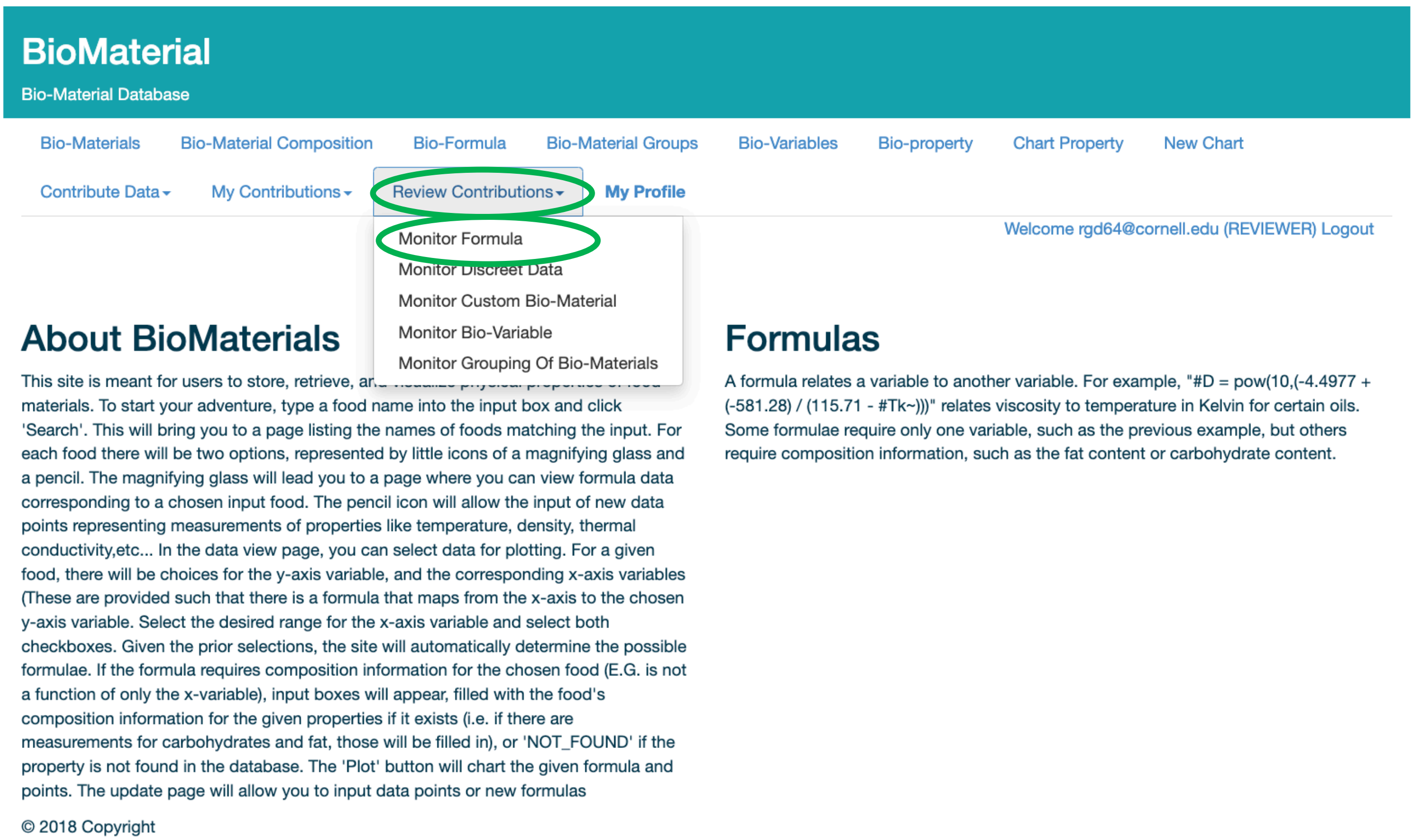
SECTION 4: VALIDATION

General validation within the database is crucial to ensure accuracy and reliability of all entries pertaining to formulas, material properties, and material associations. Every input into the database must be reviewed and cross-checked against known result and standard to confirm its validity. Having this rigor in the process helps maintain the integrity of the database and ensures it remains a dependable resource for research and application.

SECTION 4.1: FORMULA VALIDATION

To consider a formula valid in this database, the validator plays a crucial role in understanding the process being modeled, the equation used, and the range of applicability. For the formula validation, the validator must audit these formulas and constantly question the formula in the database against the data from the literature or source. Furthermore, the validator must use their own discretion in determining the applicable range of materials to which these formulas may be applied to, as described below.

Step 1: In the database, select “Review Contributions” dropdown. Select “Monitor Formula”. Select a formula from this list to validate.



Step 2: Identify a formula to validate in the database, as well as the biomaterials associated with the formula. The example below is taken from Formula ID: 532, dielectric constant of fruits and vegetables.

Bio-Formula Details

ID	532
Name	DIELECTRIC_CONST_Fruit_veg_1999
Formula	38.57+0.1255*T+0.456*WATER-14.54*(ASH/100)-0.0037*WATER*T+0.07327*(ASH/100)*T
Y-axis Variable	diel - Dielectric Constant
Variable ID	10008
Formula Desc	The effect of ash and water content on fruit and vegetable dielectric constant
Citation	Barringer et al., 2003
DOI	J Food Sci 68: 234?239, 2003
Approved	0
Added by	
Last Updated By	dg668@cornell.edu
Initially Created at	2023-05-11 18:07:42.0
Last Upadted at	2023-06-15 17:17:11.0

Step 3: Using the citation and DOI, locate the article and source to begin the validation process. Users should try accessing through their institution or department if the sources are restricted.

Dielectric properties of vegetables and fruits. . .

Table 2—Predictive equations for the dielectric constant and the loss factor of the samples at 2450MHz.

Dielectric constant	
Overall	$\kappa' = 38.57 + 0.1255 \cdot T + 0.4546 \cdot M - 14.54 \cdot A - 0.0037 \cdot M \cdot T + 0.07327 \cdot A \cdot T$
Vegetables	$\kappa' = -243.6 + 1.342 \cdot T + 4.598 \cdot M - 426.9 \cdot A + 378.5 \cdot A^2 - 0.01415 \cdot M \cdot T - 0.3151 \cdot A \cdot T$
Fruits	$\kappa' = 22.12 + 0.2379 \cdot T + 0.5532 \cdot M - 0.0005134 \cdot T^2 - 0.003866 \cdot M \cdot T$
Dielectric loss factor	
Overall	$\kappa'' = 17.72 - 0.4519 \cdot T + 0.001382 \cdot T^2 - 0.07448 \cdot M + 22.93 \cdot A - 13.44 \cdot A^2 + 0.002206 \cdot M \cdot T + 0.1505 \cdot A \cdot T$
Vegetables	$\kappa'' = -100.02 - 0.1611 \cdot T + 0.001415 \cdot T^2 + 2.429 \cdot M - 378.9 \cdot A + 316.2 \cdot A^2$
Fruits	$\kappa'' = 33.41 - 0.4415 \cdot T + 0.001400 \cdot T^2 - 0.1746 \cdot M + 1.438 \cdot A + 0.001578 \cdot M \cdot T + 0.2289 \cdot A \cdot T$

T = temperature (°C), M = moisture (%), A = wet basis ash (%)

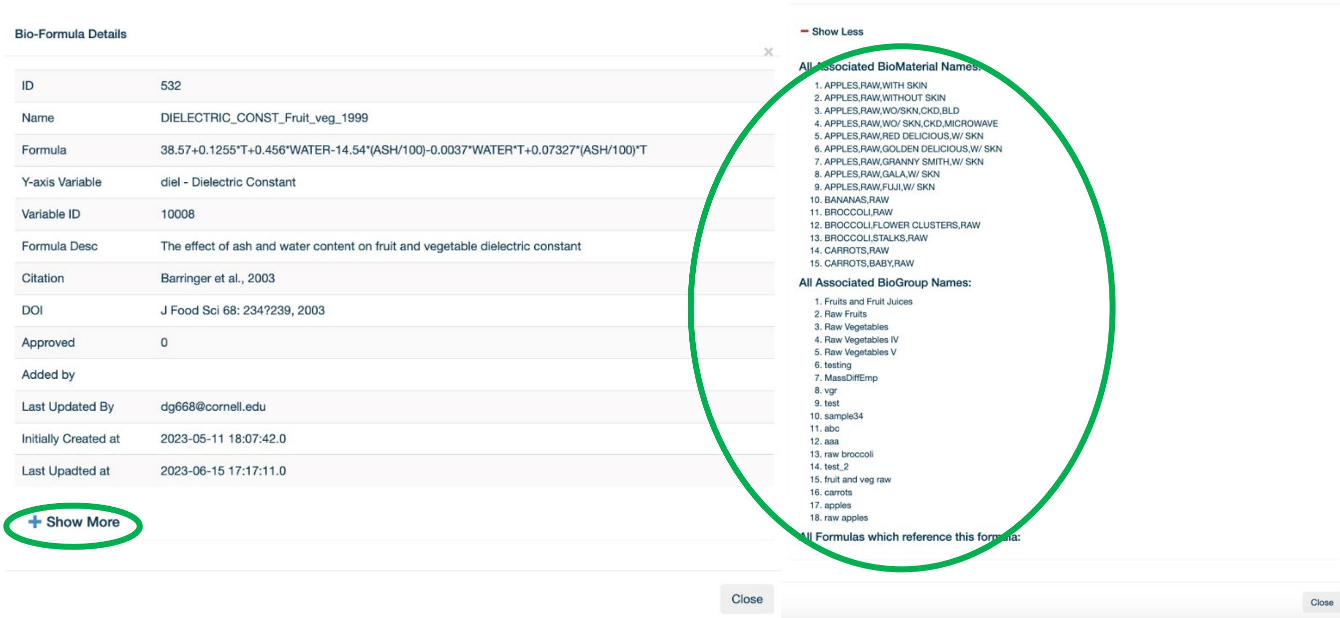
Sipahioglu, O., & Barringer, S. A. (2003). Dielectric properties of vegetables and fruits as a function of temperature, ash, and moisture content. Journal of Food Science, 68(1), 234-239.

Step 4: Users must validate the numbers and variables of this equation, and ensure the formula is taken in the correct context and units are in the correct format.

In this example, the dielectric loss factor is a dimensionless quantity, and each component of the equation yields a dimensionless result.

Step 5: Users must take the formula into context, and validate that the formula, and its variables, are used properly. It is important to understand the intent of the paper when determining the extent of use for the formula based on the empirical data.

To view the associated biomateirals and biogroups, select “Show More” within the formula window.



As shown above, all the associated materials and groups are fruits and vegetables (except for test groups). From the paper, this is a correct application of the formula. An example of a material that is not applicable to this formula, but may be considered because of certain similarities is fruit juices. Though these juices originate from raw fruits, like the materials above, fruit juices have a much higher water content and differ drastically in composition and processing and therefore is not applicable.

Smaller discerning may be necessary for other materials and formulas, such as distinguishing parts of the same material. For example, the flesh of a potato is different from the skin of a potato, and this difference may compromise the application of certain formulas. In these cases, it is important for the user to understand the rationale and logic of the formula and literature to determine what is appropriate.

Step 6: Ensure that the formula is properly formatted in the database using the following rules:

- Allowed Operators:
  - Addition: 2 + 2
  - Subtraction: 2 - 2
  - Multiplication: 2 * 2
  - Division: 2 / 2
  - Exponentiation: 2 ^ 2
  - Unary Minus,Plus (Sign Operators): +2 - (-2)
  - Modulo: 2 % 2
- Allowed Functions
  - abs: absolute value
  - acos: arc cosine
  - asin: arc sine

- atan: arc tangent
- cbrt: cubic root
- ceil: nearest upper integer
- cos: cosine
- cosh: hyperbolic cosine
- exp: euler's number raised to the power (e^x)
- floor: nearest lower integer
- log: logarithmus naturalis (base e)
- log10: logarithm (base 10)
- log2: logarithm (base 2)
- sin: sine
- sinh: hyperbolic sine
- sqrt: square root
- tan: tangent
- tanh: hyperbolic tangent
- signum: signum function

• Any Defined Formula. Use Name of the formula

Step 7: Using the chart property function of the database, the graphed data may be compared to that of the source. To validate the formula to its extent. Follow the steps in **Section 2.1**. Ensure the compositional data and biomaterial matches that of the original source. Below is the predictive chart (left) and source data (right), circled is the source water content and ash percentage, and the highlighted portion is the dielectric loss with respect to temperature for a raw carrot.

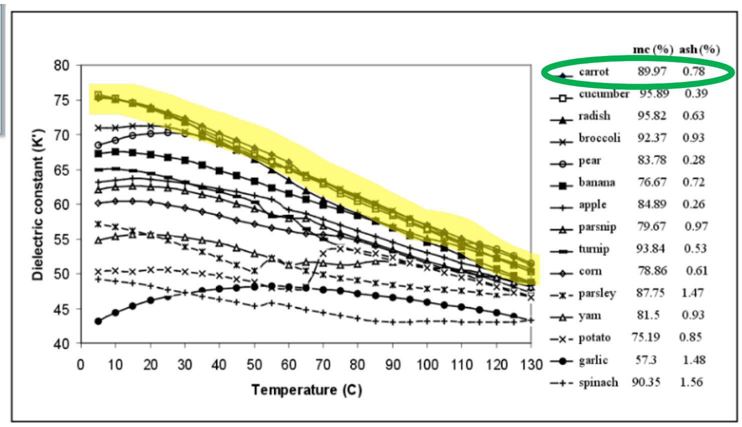


Figure 2—The effect of ash concentration and moisture on dielectric constant of vegetables and fruits at 2450MHz

Sipahioglu, O., & Barringer, S. A. (2003). Dielectric properties of vegetables and fruits as a function of temperature, ash, and moisture content. Journal of Food Science, 68(1), 234-239.

Step 8: Analyze the results. In this example, dielectric loss of raw carrots decreases with increasing temperature, consistent with the predictive chart and source data indicating the general trend is apparent. However, the actual values of the predictive formula differ slightly from the source data due to simplifications and assumptions of the formula, but these differences are minor in the predictive nature. The big things to note here are the trend, axis order of magnitude, and general alignment with the source data.

SECTION 5: USE EXAMPLES: MANUFACTURING, RESEARCH AND EDUCATION

For access to modules mentioned below, contact prof. Ashim Datta at akd1@cornell.edu.

This portion of the manual showcases a range of real-world applications that demonstrate the practical utility of the database. These examples are meant to provide inspiration and guidance to users seeking to leverage this database to solve complex problems or innovate their own work. Aiming to highlight tangible benefits and impact of food properties helps engage and motivate users to explore the full potential of this resource.

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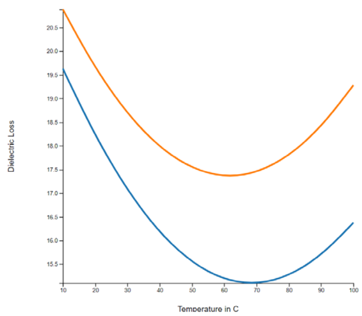
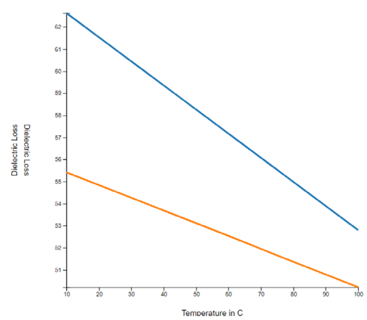
1. Directionality in design of a new process or for a new formulation. In designing a drying process for a new material, a quick estimate of moisture diffusivity would give an idea of how much the drying time needed to be extended or reduced. Of course, properties alone cannot predict a complex process (here size, water content, etc., would also have effect) but a critical property like moisture diffusivity in drying is an important process predictor. The near-instantaneous nature of the prediction greatly minimizes the time and resource needs.
2. Feasibility studies for novel ideas. For example, in planning a new microwaveable dinner, if we want to know how the chicken and the potatoes might heat relative to each other. One of the measures of this relative heating is their dielectric properties, as noted below (Yellow is chicken; blue is potato), obtained in a couple of minutes, saving time and resources by reducing the amount of experimentation.





3. Confidential storing of proprietary composition and properties for building a knowledge base for the product line for the manufacturer.

RESEARCH USE EXAMPLE

1. Food being a complex material, its properties are hard to find. If we need a likely range of properties data for a range of composition, temperature, etc., the database can provide this information in a couple of minutes, as opposed to many hours trying to search through research literature. We can even change the composition of the existing material to make these estimates as close as possible to our need.
2. In future, it should be possible to dump the properties data into a file readable in COMSOL, thus linking properties data to analysis.

EDUCATION USE EXAMPLE

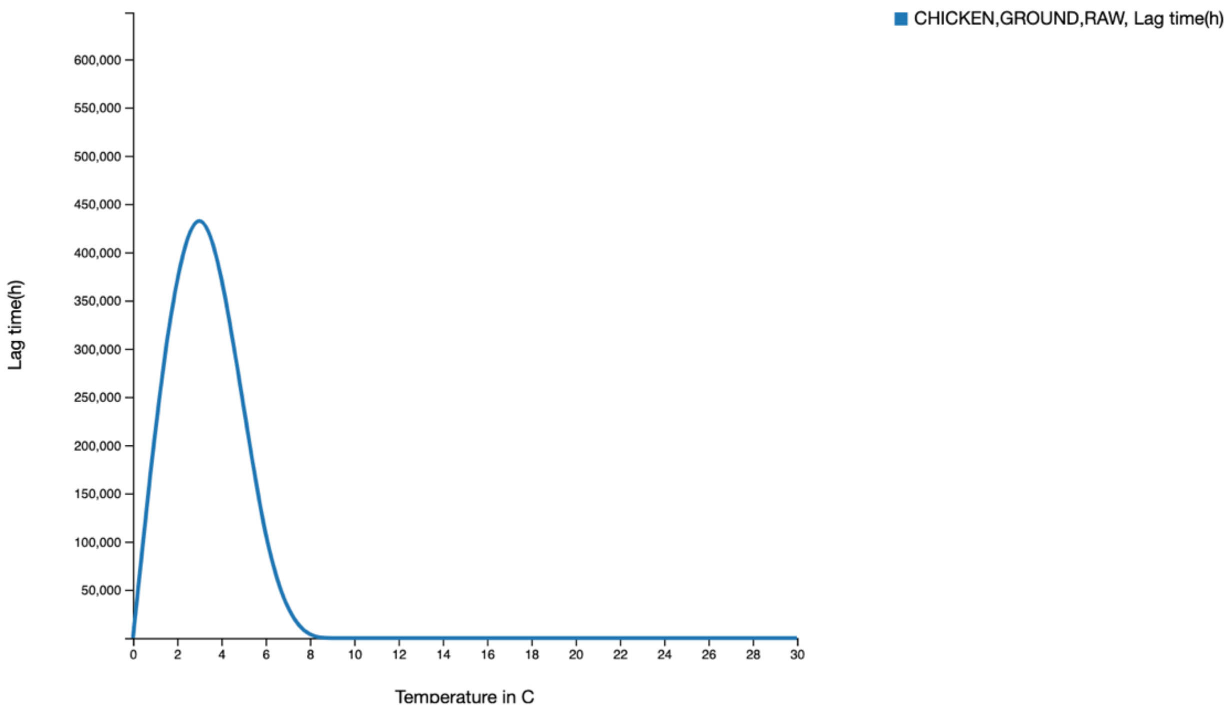
An instructional module on Canvas to learn about thermal conductivity uses the database to make the learner active. Questions currently include three areas— 1) comparison between property prediction and direct measurement, 2) comparison between different approaches to property prediction with different underlying physics, and 3) understanding the difference between materials from their estimated thermal conductivity data.

SECTION 5.1: MANUFACTURING EXAMPLES

This section provides practical manufacturing examples to show the application of the database in real-world scenarios. Each example demonstrates how specific data and predictive models in the database can optimize user manufacturing processes. These examples highlight the versatility of the database and encourage users to leverage its capabilities.

SECTION 5.1.1: PREVENTING MICROBIAL GROWTH OF RAW CHICKEN

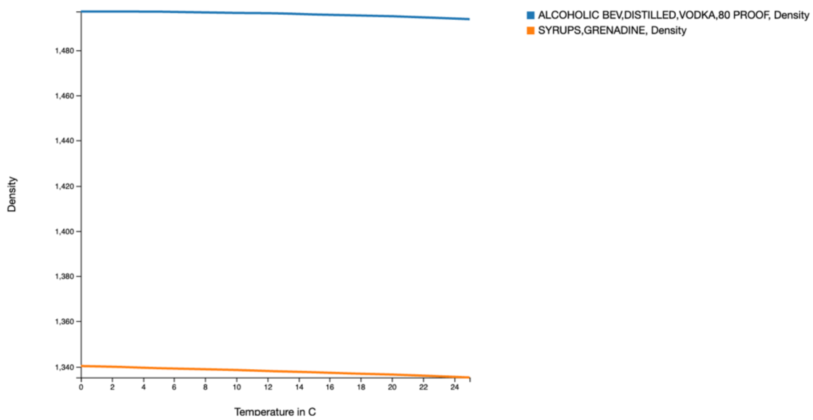
Leveraging the water activity of an ingredient can be essential in maintaining shelf life and reduced waste from spoilages. By monitoring this property over a range of temperatures, one may be able to better optimize their food and inventory. Below is an example involving raw ground chicken (5332), observing the lag time as temperature increases by following the steps outlined in Section 1 of Data Retrieval. Lag time is important to a restaurant because it allows optimal temperatures for a product to prevent the time microbial growth begins. Another material may be added by following the steps in Section 2 of Data Retrieval.

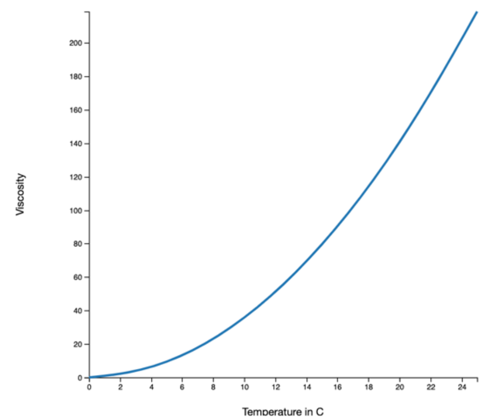


From the data charted above, it may be noted that the lag time of raw ground chicken may be observed around 4 °C and reflects the minimal growth conditions for spoilage microorganisms. As the temperature rises above 8 °C. conditions become conductive to rapid growth and decrease the lag phase that allows for immediate growth of spoilage microorganisms. This trend highlights the importance of temperature maintenance in storage conditions of raw ground chicken.

SECTION 5.1.2: CHANGES IN DENSITY AND VISCOSITY OF ALCOHOL AND MIXERS

Bartenders and mixologists may also use this database by observing the changing properties of alcohol and mixers. Below is an example involving Vodka and grenadine syrup, both commonly used together in making cocktails. Observing the changes in density and viscosity of these materials can help bartenders gain insight on serving these drinks at the correct temperature, depending if the drink is to be indulgent (thicker) or refreshing (thinner), or if it is to be layered, which relies on density. (Note these are two different displays obtained from two separate 'Chart Property' inputs.)

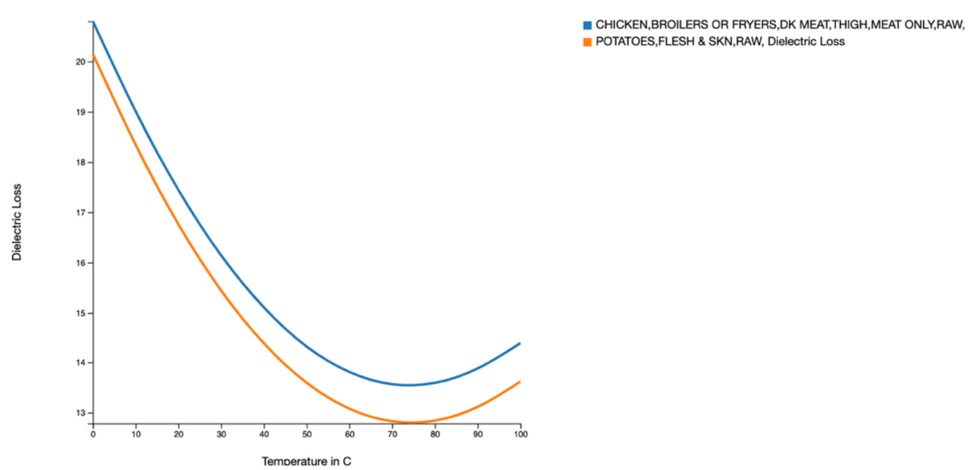




The density of vodka is higher than grenadine because of its higher water content, and both densities decrease with rising temperature due to the increasing molecular movement. The viscosity of vodka and grenadine (overlapped in this chart) increases with temperature because ethanol's molecules become more mobile and interact less with each other as temperature increases which leads to a decrease in the fluid's resistance to flow. Furthermore, the density of grenadine also increases because the syrup thickens when heated.

SECTION 5.1.3: MICROWAVE HEATING OF CHICKEN AND POTATOES

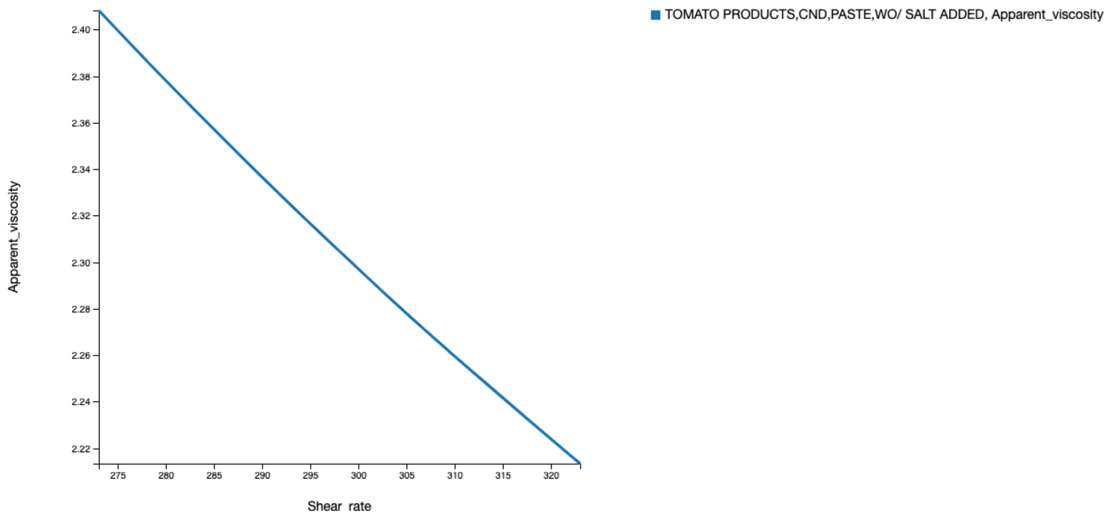
If a user were planning a new microwaveable dinner and wants to know how chicken and potatoes might heat relative to each other, measuring of their relative heating through their dielectric properties may be performed, as noted below (chicken ID: 5046, potato ID: 11352), obtained in a couple of minutes, saving time and resources by reducing the amount of experimentation.



The dielectric loss of raw chicken and potatoes decrease from 0 to 75 °C due to reduced molecular relaxation and loss of water content but curves up after 75 °C because proteins and starches denature at this temperature. The dielectric loss of chicken is greater than potatoes overall because chicken has higher protein content and less carbohydrate content, both of which contribute to significant dielectric loss, though both materials follow the same trend.

SECTION 5.1.4: MANAGING APPARENT VISCOSITY IN TOMATO PASTE

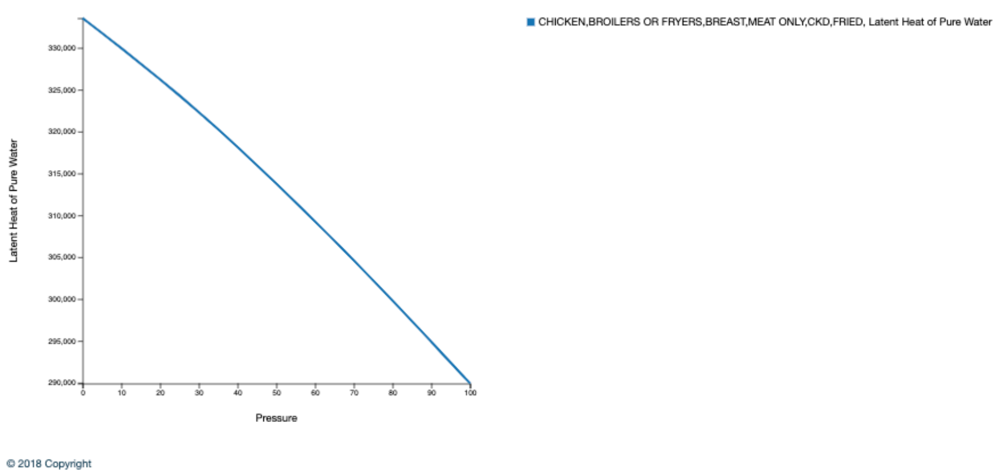
For processing certain foods that involve ingredients in a viscous liquid form, apparent viscosity plays an important role to ensure that the material flows properly through a tube or pipe. For example, a factory making large amounts of ketchup may be inclined to move as much tomato paste as possible, but need to be mindful of the viscosity of the paste relative to the shear rate, or the flow through the pipe. Below is a chart displaying this information.



The apparent viscosity of tomato paste decrease with increasing shear rate due to the shear-thinning behavior of the material, where the alignment of suspended particles and breakdown of structure reduce the resistance to flow. This allows the tomato paste to become less viscous under high shear conditions, making it easier to handle and process.

SECTION 5.1.5: FREEZING PROCESS OPTIMIZATION FOR MICROWAVABLE MEALS

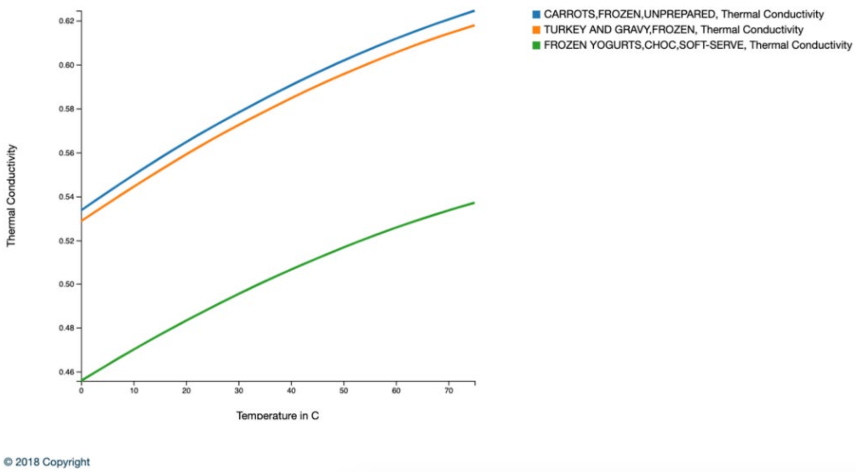
If a food processing company wished to package ready-to-eat microwavable meals, information on the freezing process of common microwavable meal foods, like chicken, is valuable. Charting and observing how the latent heat of pure water varies with pressure can help this company optimize the freezing process as it may increase the efficiency of the freezing process and ensuring the water content of the chicken freezes properly.

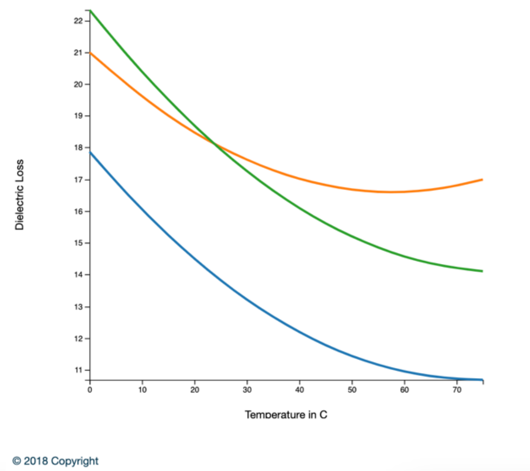


The latent heat of pure water in fried chicken breast decreases with increasing pressure because the high-pressure forces water molecules closer together and reduces the energy required to change phase from liquid to vapor. This results in lower latent heat with increasing pressure and reflects the decreased enthalpy change needed for the change in phase.

SECTION 5.1.6: THERMAL CONDUCTIVITY OF FROZEN CARROTS, TURKEY, AND YOGURT

If a user wishes to observe the heating process of various components of a microwavable dish, they can do so with ease by comparing multiple materials. For a classic microwavable meal containing frozen carrots, turkey and gravy, and chocolate yogurt, the following chart was constructed displaying the thermal conductivity of each material at various temperatures to determine the optimal heating. Furthermore, a similar chart was performed for dielectric loss as it relates to microwavable heating. The materials charted below are frozen carrots (11130), frozen turkey and gravy (5286), and frozen chocolate yogurt (19393).





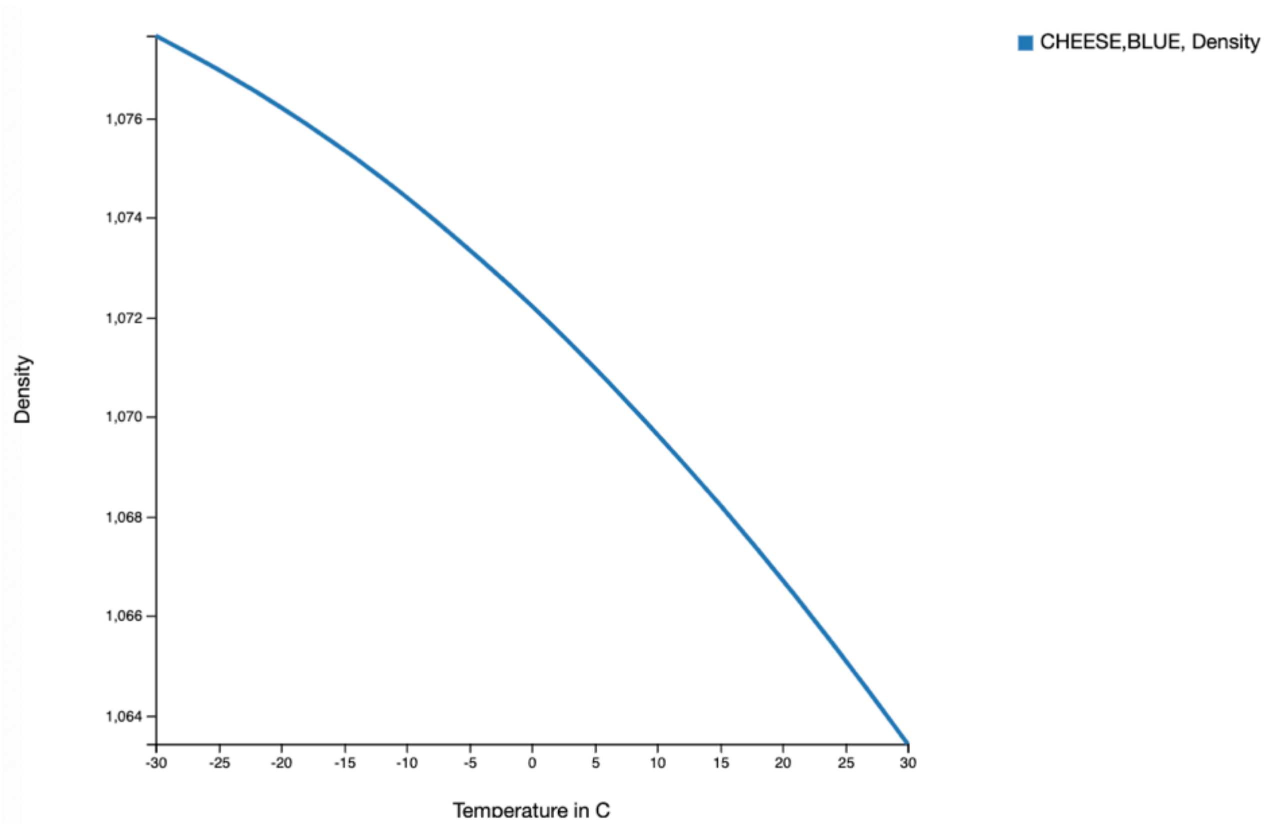
The thermal conductivity of frozen carrots, frozen turkey and gravy, and frozen chocolate yogurt increases with rising temperature because the molecular vibrations and movement within the material increase allowing more heat transfer. Rigid, frozen materials will have lower conductivity, but as the temperature increases, the molecules gain momentum and mobility and more easily facilitate heat transfer. Frozen carrots have higher water content and more homogenous structure, leading to the highest overall thermal conductivity. Subsequently, turkey and gravy and yogurts due to lesser water content and complex, heterogenous structure. The dielectric loss of all these materials decreases with increasing temperature due to the increasing molecular motion that reduces the ability of dipoles to align with the alternating electric fields, lowering the material's ability to dissipate electrical energy as heat.

SECTION 5.2: RESEARCH USE EXAMPLES

This section provides detailed examples of how this database may be utilized for research purposes. Each example demonstrates the application of the database in addressing specific research questions and is meant to optimize experimental designs by allowing users to determine quick, reliable data of various foods and food properties. These examples show the database's role in facilitating efficient research workflows and enhances quality of research output.

SECTION 5.2.1: FOOD SAFETY EXAMPLE

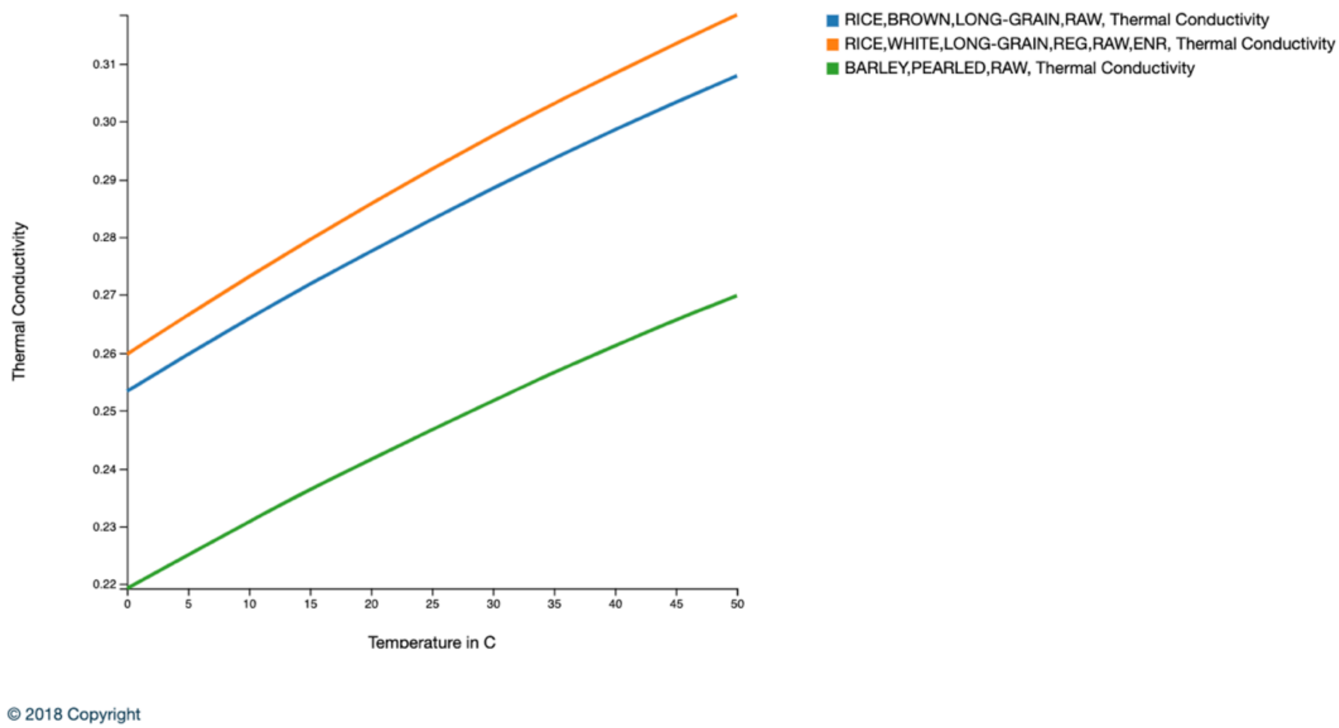
Ensuring that the desired texture, consistency, and maintenance of mold is crucial for substances like blue cheese that have delicate physical properties and are required to maintain at specific condition. Understanding how density changes with temperature for this product aids in determining how other properties may be affected. Below is a graph of these variables for blue cheese (1004) that may be used to ensure this product retains its integrity in many aspects.



The density of blue cheese decreases with increasing temperature because heat will cause the fat and water content to expand and increase the volume while the mass remains constant. The molecules will move farther apart, and the cheese structure will become less compact as thermal expansion leads to lower density.

SECTION 5.2.2: COMPARITIVE ANALYSIS

Suppose a food scientist wanted to determine the optimal grain for a certain drying process, comparing between white rice, brown rice, and barley. Instead of having to individually test the thermal conductivity for each grain, the researcher may use the database knowing that an increased thermal conductivity may lead to a faster and more uniform drying process.



The thermal conductivity of brown rice, white rice, and barley increases with increasing temperature because high temperatures increase molecular vibrations and movement resulting in efficient heat transfer. White rice has the highest thermal conductivity due to its refined structure, while brown rice has a bran layer that decreases heat flow. Barley has the lowest relative thermal conductivity due to its fibrous nature.

SECTION 5.2.3: CUSTOMIZING CATALOGED MATERIALS EXAMPLE #1

The ability to customize materials within the database can be important to product developers by allowing them to cater to a diverse consumer preference and provide differentiation from the current material. In this example, the composition of a lasagna is altered based on recipes found online, instructing users how they can further utilize this database to their specific need and observe the behavior of their material.

Suppose a user wanted to edit the lasagna composition based on the following recipe for their version of lasagna.

Step 1: Follow Section 1: Steps 1-11 found in Data Retrieval. The item used is restaurant lasagna (36041) and the material composition is displayed below.

Material Composition Values	Material Composition 1	Material Composition 2	Material Composition 3	Material Composition 4	Material Composition 5

Material Composition 1

Material Composition	Unit	USDA Value	Change Value(Optional)
Water	g	64.87	64.87
AIR	g	0	0
ICE	g	0	0
Protein	g	10.83	10.83
Carbohydrate, by difference	g	11.36	11.36
Total lipid (fat)	g	10.69	10.69
Fiber, total dietary	g	1.5	1.5
Ash	g	2.25	2.25

Step 2: For the new lasagna recipe, determine the ingredients and quantity of each in grams.

- Lasagna Noodles (32010): 300 grams
- Ground Beef (13285): 500 grams
- Ricotta Cheese (1036): 250 grams
- Mozzarella Cheese (1026): 200 grams
- Tomato Sauce (6960): 400 grams
- Total mass of lasagna: 1700 grams

Helpful Tip: When working with multiple materials, note the ID number associated with the material. These can be found next the material in most dropdowns, or in 'Details' if searched in the 'Bio-Materials' tab (See "Getting Oriented: Biomaterials"). This will ensure efficient and accurate searching and charting of the material.

Step 3: Determine the compositional values of each ingredient, that is, determine the protein, carbohydrate, lipid, fiber, water, and ash quantities in grams per 100 grams. Values obtained below are estimations retrieved from database.

Ingredient	Protein (g)	Carbohydrate (g)	Lipid (g)	Fiber (g)	Water (g)	Ash (g)	Total (g)
Lasagna Noodles	11	74	2	3	7	5	100
Ground Beef	30	0	10	0	58	2	100
Ricotta Cheese	11	3	13	0	72	1	100
Mozzarella Cheese	22	2	22		50	3	100
Tomato Sauce	1	7	1	1	88	2	100

Step 4: Calculations of each using the information from the steps above. Every composition will have a calculation for each ingredient. The example for protein only:

$$Lasagna\ Noodles: 300\ grams\ of\ Lasagna\ Noodles * (11\ grams\ of\ protein)/(100\ grams\ of\ Lasagna\ Noodles) = 33\ grams\ of\ protein$$

$$Ground\ Beef: 500\ grams\ of\ Ground\ Beef * (30\ grams\ of\ protein)/(100\ grams\ of\ Ground\ Beef) = 150\ grams\ protein$$

$$Ricotta\ Cheese: 250\ grams\ of\ Ricotta\ Cheese * (11\ grams\ of\ protein)/(100\ grams\ of\ Ricotta\ Cheese) = 27.5\ grams\ of\ protein$$

$$Mozzarella\ Cheese: 200\ grams\ of\ Mozzarella\ Cheese * (22\ grams\ of\ protein)/(100\ grams\ of\ Mozzarella\ Cheese) = 44\ grams\ of\ protein$$

$$Tomato\ Sauce: 400\ grams\ of\ Tomato\ Sauce * (1\ grams\ of\ protein)/(100\ grams\ of\ Tomato\ Sauce) = 4\ grams\ of\ protein$$

From these calculations, it can be determined that this lasagna has 269 total grams of protein. Next, determine the grams of protein per 100 grams of lasagna as this value will be entered as the composition value for protein.

$$Total\ Protein\ (grams): 100 * (258.5\ grams\ of\ protein)/(1650\ total\ grams\ of\ lasagna) = 15.67\ grams\ of\ Protein$$

Step 5: Repeat these calculations for every compositional group.

$$Total\ Water\ (grams): 100 * (942\ grams\ of\ Water)/(1650\ total\ grams\ of\ lasagna) = 57.10\ grams\ of\ Water$$

$$Total\ Carbohydrate\ (grams): 100 * (261.5\ grams\ of\ Carbohydrate)/(1650\ total\ grams\ of\ lasagna) = 15.85\ grams\ of\ Carbohydrate$$

$$Total\ Lipid\ (grams): 100 * (136.5\ grams\ of\ Lipid)/(1650\ total\ grams\ of\ lasagna) = 8.27\ grams\ of\ Lipid$$

$$Total\ Fiber\ (grams): 100 * (13\ grams\ of\ Fiber)/(1650\ total\ grams\ of\ lasagna) = 0.79\ grams\ of\ Fiber$$

$$Total\ Ash\ (grams): 100 * (41.5\ grams\ of\ Ash)/(1650\ total\ grams\ of\ lasagna) = 2.51\ grams\ of\ Ash$$

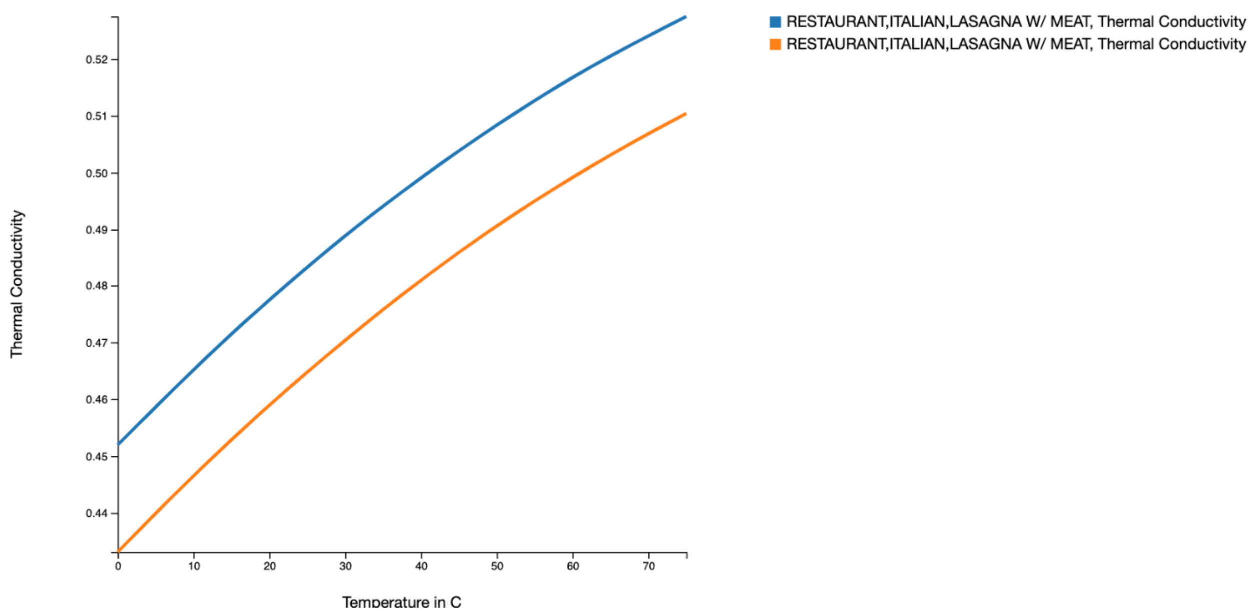
Step 6: Repeat Step 1 of this section, adding a second material, and change the compositional values to the calculated ones of the custom lasagna.

Material Composition 2

Material Composition	Unit	USDA Value	Change Value(Optional)
Water	g	64.87	57.1
AIR	g	0	0
ICE	g	0	0
Protein	g	10.83	15.67
Carbohydrate, by difference	g	11.36	15.85
Total lipid (fat)	g	10.69	8.27
Fiber, total dietary	g	1.5	0.79
Ash	g	2.25	2.51

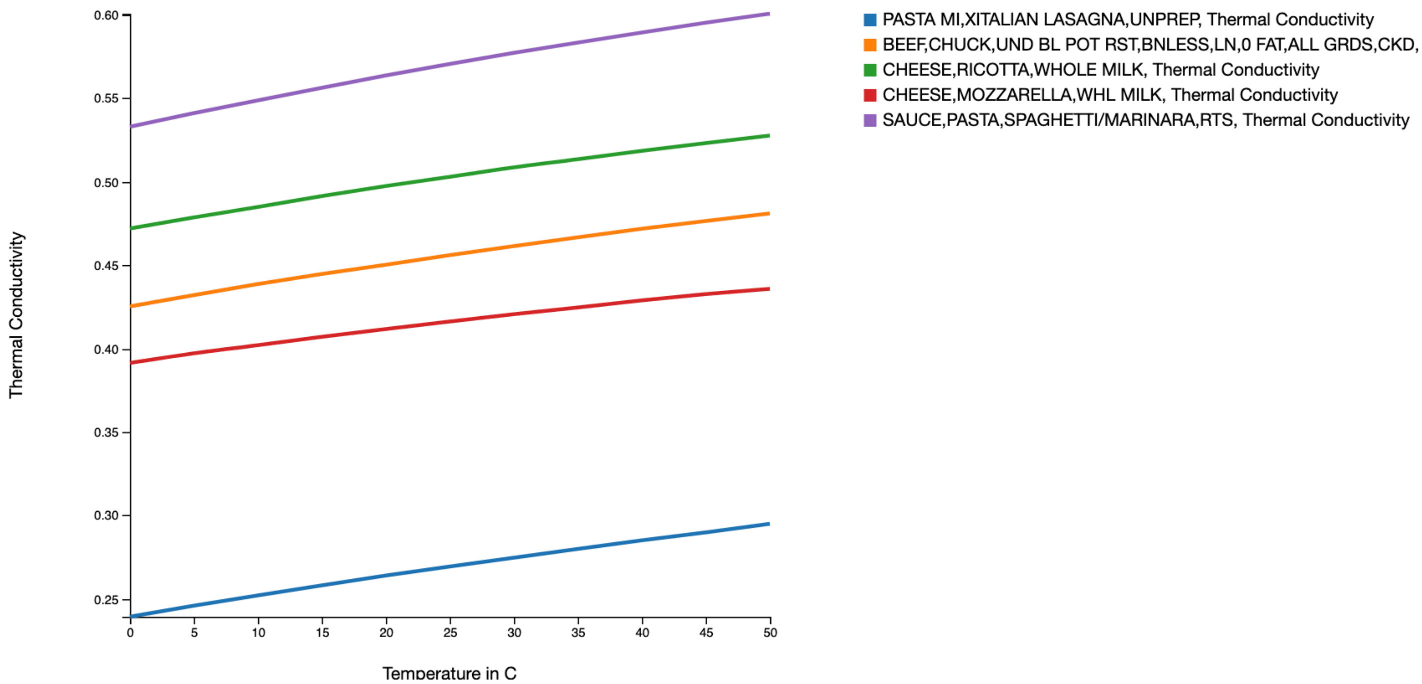
Chart Bio-Material Formula

Step 7: Chart the two lasagnas. The orange line is the new, custom lasagna with adjusted composition parameters.



A lasagna with lower water content and higher protein and carbohydrate content has higher relative thermal conductivity because proteins and carbs are better heat conductors than water. Thermal conductivity increases with temperature because higher temperature increase the molecular vibrations and increase the efficiency of heat transfer.

Optional Step: The individual ingredients may also be graphed together to observe the behavior of each component in the lasagna.



Pasta has the highest relative thermal conductivity than the other ingredients because of its dense structure that allows efficient heat transfer. Beef has a high fat content and lower thermal conductivity due to the insulating properties of fat. Ricotta and mozzarella cheese, along with spaghetti sauce, have lower thermal conductivity due to higher water content and less dense strcutre. Ricotta cheese has higher moisture content and allows for more efficient heat transfer than mozzarella cheese.

Like the previous example, the compositional values of every item in the database may be edited to tune a certain product to the user's liking. In this example, Swanson's Chicken a la King is edited based on a slightly different recipe.

Step 1: Follow Section 1: Steps 1-11 found in Data Retrieval. The item used is Swanson Chicken a la King (22951) and the material composition is displayed below for charting density as a function of porosity.

Material Composition Values	Material Composition 1	Material Composition 2	Material Composition 3	Material Composition 4	Material Composition 5

Material Composition 1

Material Composition	Unit	USDA Value	Change Value(Optional)
Water	g	80.1	80.1
AIR	g	0	0
ICE	g	0	0
Protein	g	4.7	4.7
Carbohydrate, by difference	g	4.03	4.03
Total lipid (fat)	g	4.03	4.03
Fiber, total dietary	g	0.7	0.7
Ash	g	7.15	7.15
T	C	0	0

Step 2: For the new chicken recipe, determine the ingredients and quantity of each in grams.

- Canned Chicken with Broth (5277): 300 grams
- Canned Red Peppers (11916): 100 grams
- Canned Mushrooms (11264): 100grams
- Vegetable Oil (4670): 30 grams
- Wheat Flour (20080): 50 grams
- Total mass of lasagna: 580 grams

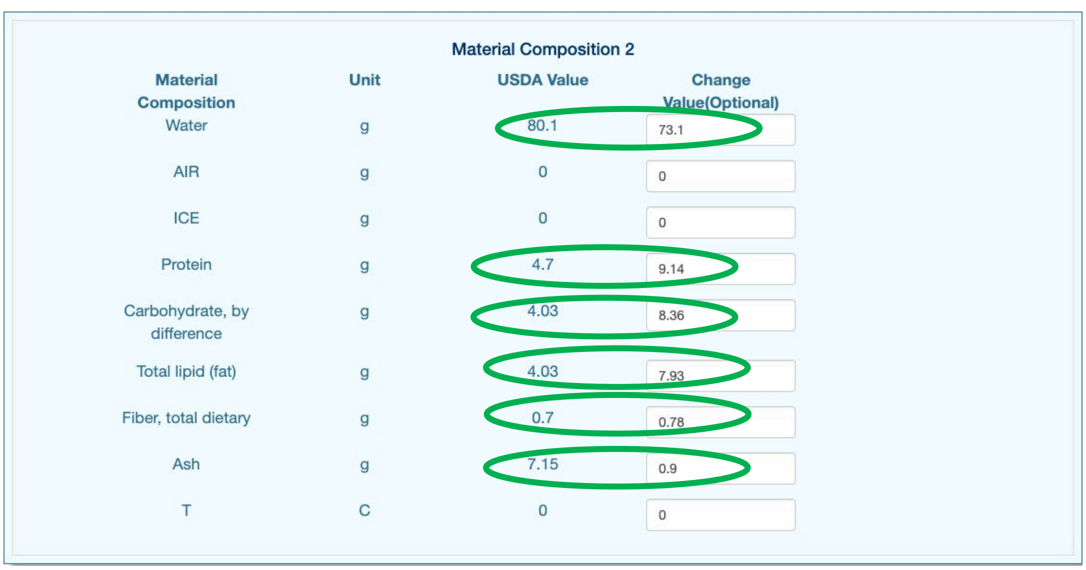
Step 3: Determine the compositional values of each ingredient, that is, determine the protein, carbohydrate, lipid, fiber, water, and ash quantities in grams per 100 grams. Values obtained below are estimations retrieved from database.

Ingredient	Protein (g)	Carbohydrate (g)	Lipid (g)	Fiber (g)	Water (g)	Ash (g)	Total (g)
Chicken (Broth)	22	0	8	0	68	2	100
Red Peppers	1	4	0	1	91	3	100
Mushrooms	1	5	0	2	91	1	100
Vegetable Oil	0	0	100	0	0	0	100
Wheat Flour	13	72	2	6	6	1	100

Step 4: Repeat steps 4-6 of the previous section and edit these components to be charted.

Material Composition 1

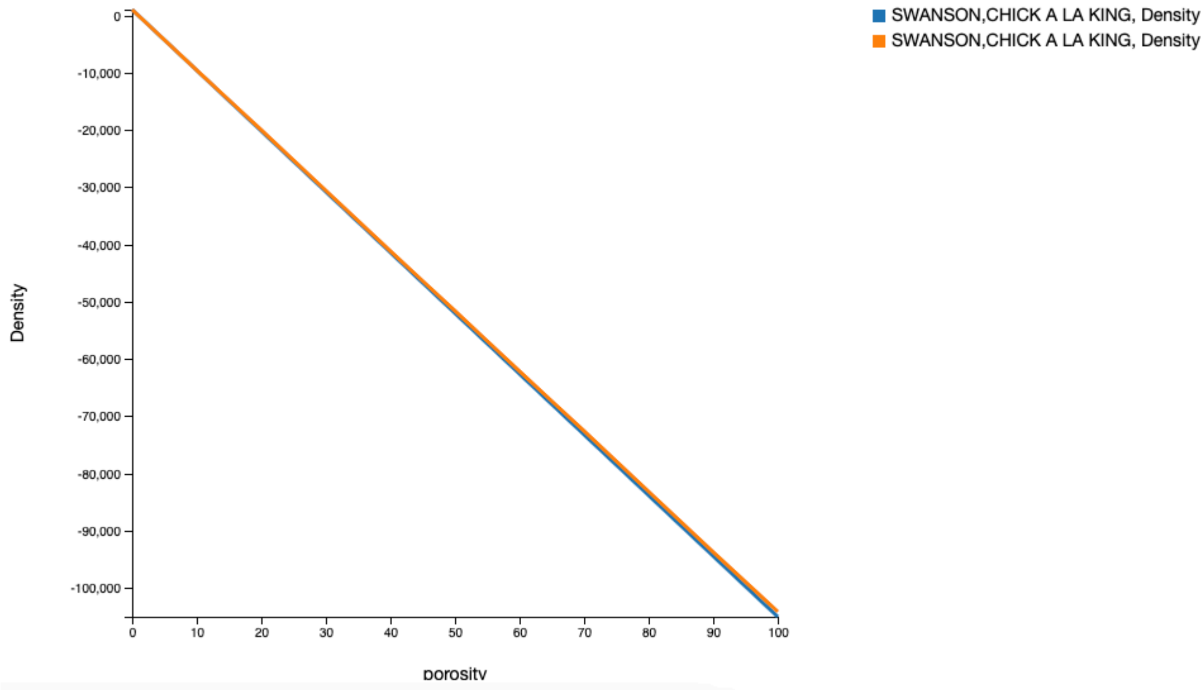
Material Composition	Unit	USDA Value	Change Value(Optional)
Water	g	80.1	80.1
AIR	g	0	0
ICE	g	0	0
Protein	g	4.7	4.7
Carbohydrate, by difference	g	4.03	4.03
Total lipid (fat)	g	4.03	4.03
Fiber, total dietary	g	0.7	0.7
Ash	g	7.15	7.15
T	C	0	0



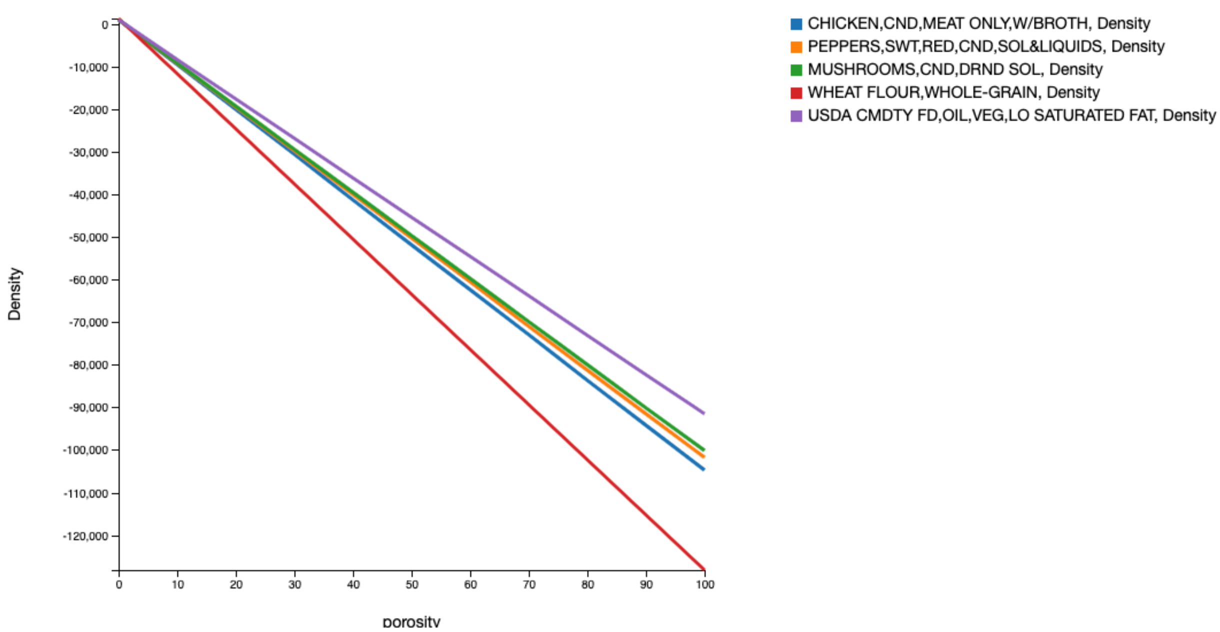
Material Composition 2

Material Composition	Unit	USDA Value	Change Value(Optional)
Water	g	80.1	73.1
AIR	g	0	0
ICE	g	0	0
Protein	g	4.7	9.14
Carbohydrate, by difference	g	4.03	8.36
Total lipid (fat)	g	4.03	7.93
Fiber, total dietary	g	0.7	0.78
Ash	g	7.15	0.9
T	C	0	0

Step 7: Chart the two meals. The orange line is the new, custom lasagna with adjusted composition parameters.



Optional Step: The individual ingredients may also be graphed together to observe the behavior of each component in the Swanson meal.

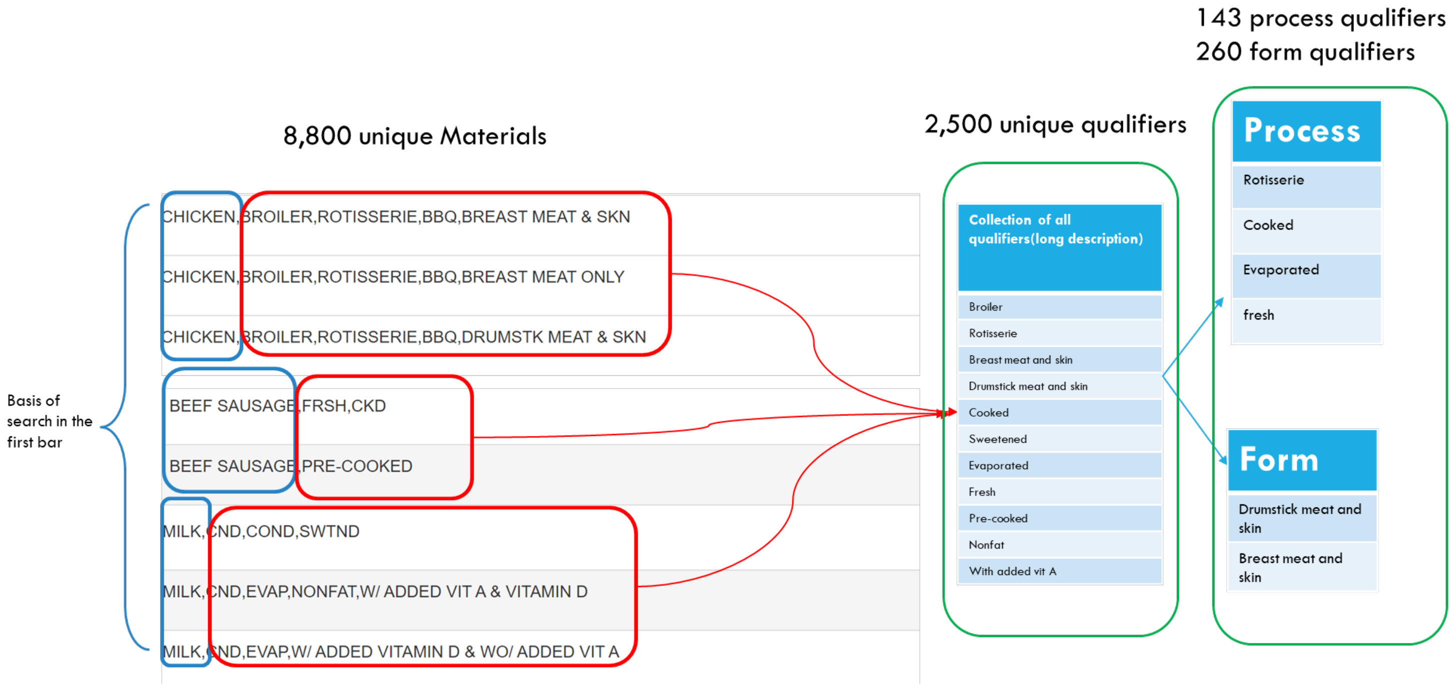


The properties graphed here visualize how density changes with porosity. This may be important for a user because the results show that density decreases as porosity increases, indicating that the product becomes less compact (dense) and more airy. The compactness and airiness of Chicken a la King is important because this product has a creamy and dense consistency, so ensuring that the porosity does not become too high is crucial in maintaining its characteristic texture.

SECTION 6.1: OVERVIEW OF THE PREDICTION PROCESS

The database holds prediction equations and discrete property data from published literature. The composition data come from the **-year old composition database from the US Department of Agriculture. Since the literature data is typically for a very restricted material (sometimes just specific to that experiment), we do generalize the predictions to a broader group of same material from different sources or even similar materials.

The search logic is shown in the figure below.



SECTION 6.2: SOURCE OF PROPERTIES DATA AND EQUATIONS

Only refereed publications in well-known engineering and food science journals are included. Once input, the data visualization is cross-checked against the source and, at times, against related work. They should also pass our general qualitative understanding. Important to note that we are not being a gatekeeper of data. All published data are included but some get extra scrutiny if the trends are contrary to general understanding.

Composition data for about 9000 materials are included from the USDA database. About 750+ predictive formulas are included for the following properties:

1. Activation Energy
2. Apparent Density
3. Apparent Viscosity
4. Bound Water Mass Fraction
5. Consistency Coefficient
6. Density
7. Dielectric Loss
8. Diffusivity
9. Enthalpy
10. Initial Freezing Point
11. Initial Reaction Rate
12. Isothermal Compressibility
13. Lag Time
14. Latent Heat of Fusion
15. Maximum Specific Growth Rate
16. Porosity
17. Specific Volume
18. Thermal Conductivity
19. Thermal Expansivity
20. Viscosity
21. Water Activity

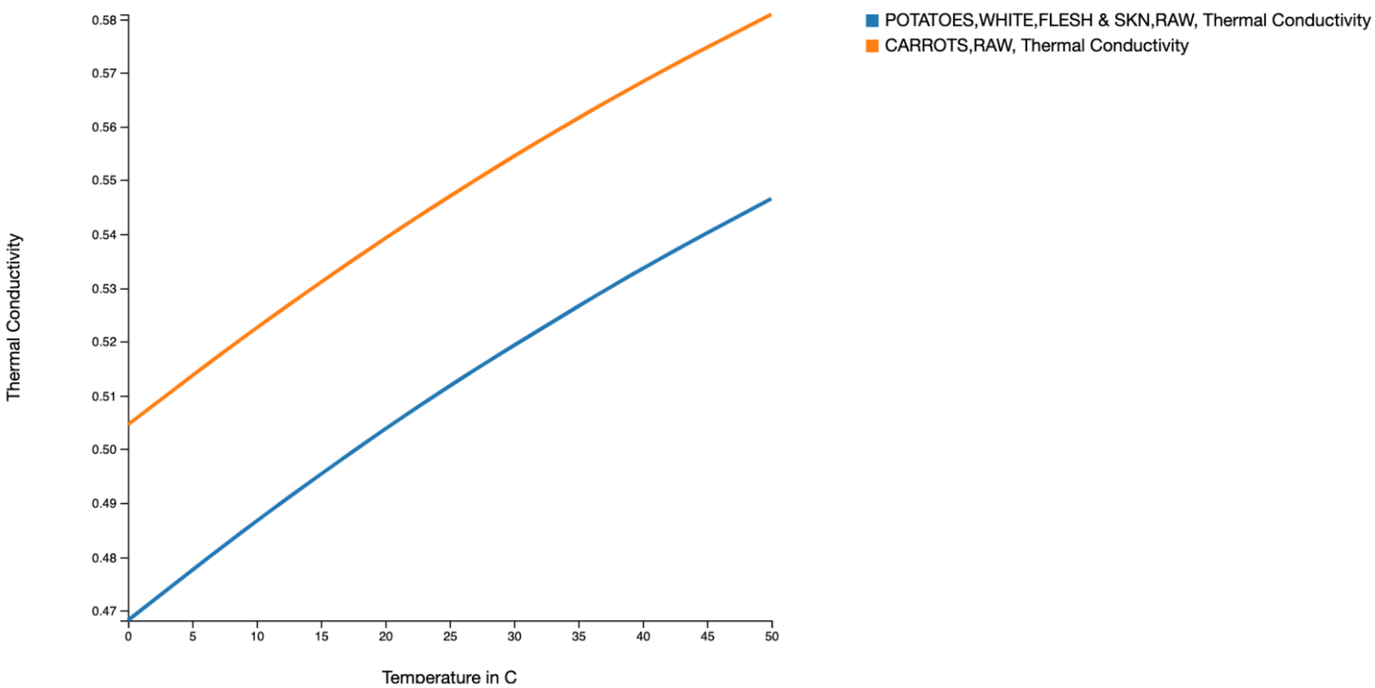
SECTION 6.3: DISCRETE DATA AND PREDICTION EQUATIONS

Types of property data include discrete data and prediction equations, with emphasis on the latter since it has much broader reach.

Looking at the formula for thermal conductivity with a series formulation, this formula may be applied to all materials because it takes into account the contribution to thermal conductivity of each component in a mixture. The formula uses volume fractions and density ratios to normalize the relative specific thermal properties.

$$\frac{1}{\left(\frac{\left(\frac{WATER}{100}\right)\times\left(\frac{RHO\_MIX}{RHO\_WATER}\right)}{K\_WATER}+\frac{\left(\frac{PROCNT}{100}\right)\times\left(\frac{RHO\_MIX}{RHO\_PROCNT}\right)}{K\_PROCNT}+\frac{\left(\frac{CHOCDF-FIBTG}{100}\right)\times\left(\frac{RHO\_MIX}{RHO\_CHOCDF}\right)}{K\_CHOCDF}+\frac{\left(\frac{FIBTG}{100}\right)\times\left(\frac{RHO\_MIX}{RHO\_FIBTG}\right)}{K\_FIBTG}+\frac{\left(\frac{ASH}{100}\right)\times\left(\frac{RHO\_MIX}{RHO\_ASH}\right)}{K\_ASH}+\frac{\left(\frac{FAT}{100}\right)\times\left(\frac{RHO\_MIX}{RHO\_FAT}\right)}{K\_FAT}+\frac{\left(\frac{ICE}{100}\right)\times\left(\frac{RHO\_MIX}{RHO\_ICE}\right)}{K\_ICE}+\frac{por}{K\_A}\right)}$$

The structure of the formula allows it to adapt to various materials by adjusting to the specific thermal conductivity values of the components involved. Here is an example using White Potatoes (11354) and Raw Carrots (11124):

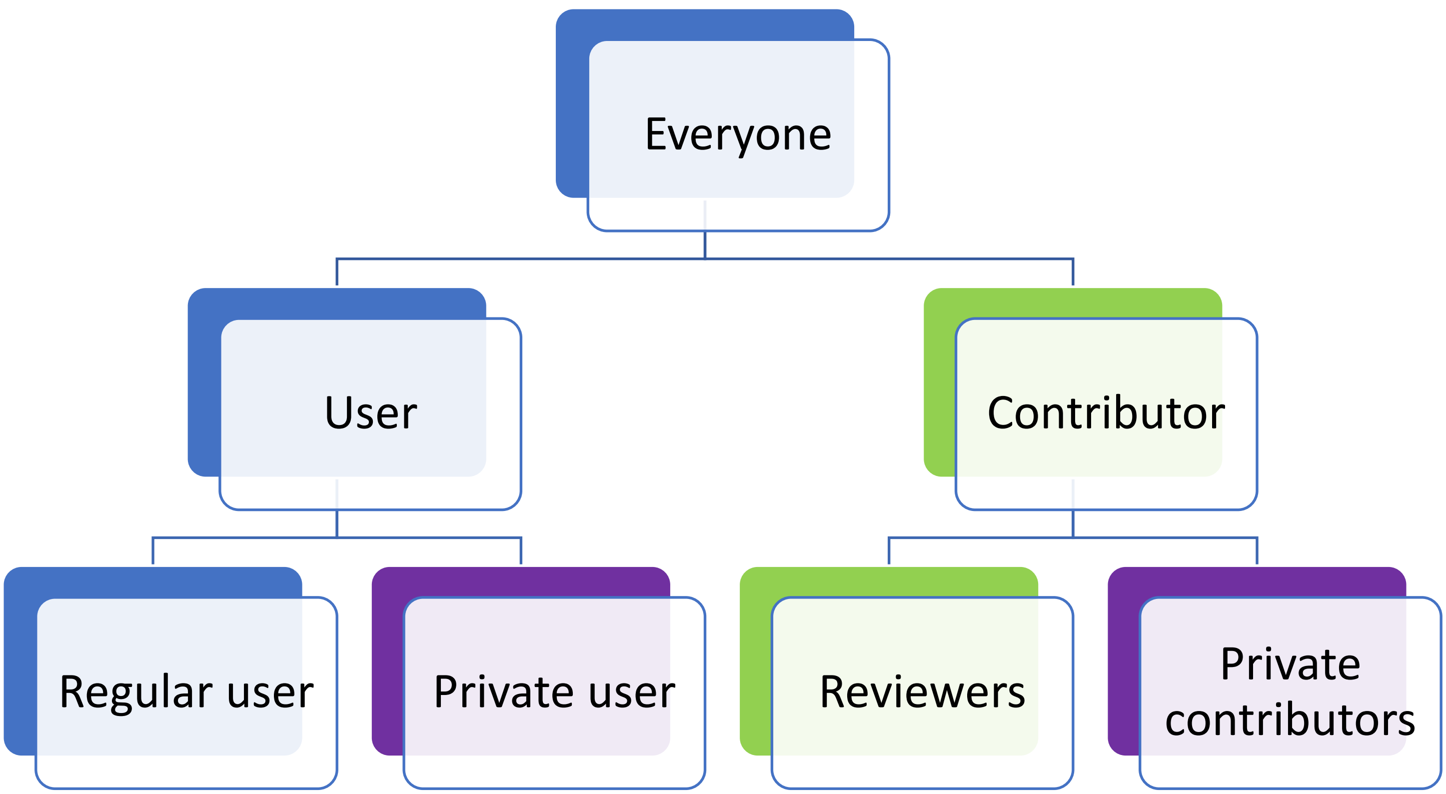


The graphs of thermal conductivity of these two materials is different despite using the same formula because of the material composition, shown below. White Potatoes (left) and Raw Carrots (right).

Material Composition 1			
Material Composition	Unit	USDA Value	Change Value(Optional)
Water	g	81.58	81.58
AIR	g	0	0
ICE	g	0	0
Protein	g	1.68	1.68
Carbohydrate, by difference	g	15.71	15.71
Total lipid (fat)	g	0.1	0.1
Fiber, total dietary	g	2.4	2.4
Ash	g	0.94	0.94
por	1	0	0

Material Composition 2			
Material Composition	Unit	USDA Value	Change Value(Optional)
Water	g	88.29	88.29
AIR	g	0	0
ICE	g	0	0
Protein	g	0.93	0.93
Carbohydrate, by difference	g	9.58	9.58
Total lipid (fat)	g	0.24	0.24
Fiber, total dietary	g	2.8	2.8
Ash	g	0.97	0.97
por	1	0	0

SECTION 6.4: CROWDSOURCING



GLOSSARY

This glossary of food properties can be invaluable for users of this database by providing clear, concise explanations of the various physical, chemical, and biological characteristics. Knowledge of these properties and how to apply them can help user influence the behavior and quality of food products. This glossary allows users leverage the full potential of this database to drive innovation, optimize processes, and ensure safety of food products.

Activation Energy: The minimum energy required to start a chemical reaction. This is crucial for understanding the temperature sensitivity of food reactions (monitoring enzymatic activity and spoilage reactions) which users can use to predict shelf life and optimize processing conditions. Relevant variables: temperature, reactant concentrations, pH level.

Apparent Density: Bulk density of a material that includes the volume of pores. Useful in packaging and storage optimization and logistical planning of transportation. Relevant variables: temperature, moisture content, porosity, composition.

Apparent Viscosity: Measure of a fluid's resistance to flow under certain conditions. Used to determine texture and flow of food products that may be vital for quality control in liquid products (sauce, dressings, soups, etc.). Relevant variables: temperature, composition, shear rate.

Bound Water Mass Friction: Portion of water in a food product that is physically or chemically bound. This is necessary for understanding the stability and shelf life of food product and can be used to design dehydration or drying processes. Relevant variables: temperature, humidity, composition.

Consistency Coefficient: Parameter that indicates fluidity thickness. Used to characterize flow behavior of fluids that may help quality control and process design for fluid products. Relevant variables: temperature, composition, shear rate.

Density: Mass per unit volume of a substance. This property is useful in determining the weight of food given its volume, and vice versa, which may be important for packaging, shipping, and portion control, as well as insight into texture and composition of material. Relevant variables: temperature, pressure, phase.

Dielectric Loss: Quantifies the energy that is dissipated in a material when exposed to an electric field. Useful for microwave heating applications that allow users to optimize heating processes for uniform cooking with reduced energy consumption. Relevant variables: Frequency of electric field, temperature, moisture content, composition.

Diffusivity: Measure of how fast a substance spreads through a medium. This can be used for the rate of nutrient or movement of contaminants within and around food products. Crucial for marination, storage, and contamination control. Relevant variables: temperature, medium content, concentration gradient, size.

Enthalpy: The total internal energy (heat) of a system. Important for calculating energy requirement in a thermal process that can help to optimize heating and cooling methods to maximize efficiency and product quality. Relevant variables: temperature, pressure, phase.

Initial Freezing Point: The temperature that food begins to freeze. Crucial for designing freezing storage processes. Helps to ensure that products freeze properly and uniformly and maintaining texture and flavor. Relevant variables: Solute concentration, pressure, impurity content.

Initial Reaction Rate: The speed that a reaction proceeds when it begins. This property may help in predicting the speed of a reaction (i.e. fermentation) and allow users to tune to their liking based on processing time and conditions. Relevant variables: temperature, catalyst presence, pH level.

Isothermal Compressibility: Measure of the relative volume change of a substance under pressure at a constant temperature. Significant for understanding food behavior in high pressure conditions and may help users optimize conditions for maintenance. Relevant variables: pressure, temperature, phase.

Lag Time: The period before the start of observable microbial growth. This is important for safety and preparation of food. Users may use this information to estimate microbial growth and aim to prevent it by changing storage and handling procedures. Relevant variables: microbial load, nutrient content, temperature.

Latent Heat of Fusion: Heat required to change a substance from solid to liquid. Useful in designing thawing processes and can help users calculate required energy for phase change to construct preservation processes and reduce energy consumption. Relevant variables: purity, pressure, phase.

Maximum Specific Growth Rate: The fastest rate an organism can reproduce under optimal conditions. This rate is critical for modeling microbial growth rate in foods and can help users construct optimal preservation strategies by predicting spoilage timeline. Relevant variables: nutrient content, oxygen availability, temperature.

Porosity: Measure of void of space in a material. Important to determine the texture and moisture retention that can help users optimize cooking processes (drying, frying) to achieve the desired product texture and consistency. Relevant variables: composition, particle distribution, moisture content.

Specific Volume: Inverse of density and represents volume per unit mass of a substance. Important for evaluating the texture and airiness of products. Relevant variables: temperature, pressure, composition, porosity.

Thermal Conductivity: Rate that heat passes through a material. Essential for designing thermal processing equipment and ensure proper heating and cooling of food product and packaging. Relevant variables: temperature, moisture content, structure.

Thermal Expansivity: Rate of material expansion with temperature. Helps in designing thermal processes (baking, cooling, freezing) to ensure uniform heating or cooling to maintain product integrity. Relevant variables: temperature, pressure, phase.

Viscosity: The measure of a fluid's resistance to flow, critical for determining the texture of food products.

Water Activity: Measure of free water in a substance available for microbial growth. Controlling such property is important in food preservation and safety. Property data can be used to predict shelf life and spoilage rate by maintaining optimal moisture level. Relevant variables: temperature, moisture content, solute concentration.

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FORMULAS IN READABLE FORMAT

The formulas of this database are compiled by the developers and users and can be found throughout. For users unfamiliar with the modelling of materials and their properties, below are examples of reformatted formulas:

1. Enthalpy of Fat:
   1.9842*(T_F-T)+(1.4733*(10^-3)*(T_F^2-T^2)/2)-(4.8008 *(10^-6)*(T_F^3-T^3)/3)

$$1.9842 \times (T_F - T) + \left(1.4733 \times 10^{-3} \times \frac{T_F^2 - T^2}{2}\right) - \left(4.8008 \times 10^{-6} \times \frac{T_F^3 - T^3}{3}\right)$$

2. Thermal Conductivity of Ice:
   2.21960 - (6.2489 * pow(10,-3) * T) +(1.0154 * pow(10,-4) * pow(T,2))

$$2.21960 - (6.2489 \times 10^{-3} \times T) + (1.0154 \times 10^{-4} \times T^2)$$

3. Consistency Coefficient for Pera Orange:
   1.096*pow(10,-8)*exp(5264/Tk+14.53*C_p)

$$1.096 \times 10^{-8} \times e^{\left(\frac{5264}{T_k} + 14.53 \times C_p\right)}$$

4. CO2 evolution of blueberry (coville cultivar) at 15 C:
   1.3*OXY_CONS_BLUEBERRY_COVILLE_15C + (51.06)/(0.18 + 0.04*p_oxy + p_co2 + 1)

$$1.3 \times \text{OXY\_CONS\_BLUEBERRY\_COVILLE\_15C} + \left(\frac{51.06}{0.18 + 0.04 \times p_{\text{oxy}} + p_{\text{co2}} + 1}\right)$$

5. Speed of sound in muscle (mixture of protein, fat, and water) at temperature T:
   (1/((m_fa/(c_fT)^2)+(m_bw/(c_wT)^2)+(m_p/(c_p)^2)))^0.5

$$\left(\frac{1}{\left(\frac{m_{\text{fa}}}{(c_{\text{fT}})^2}\right) + \left(\frac{m_{\text{bw}}}{(c_{\text{wT}})^2}\right) + \left(\frac{m_{\text{p}}}{(c_{\text{p}})^2}\right)}\right)^{0.5}$$

FORMULA VARIABLES

The following table lists variables used in predictive formulas, including descriptions of each variable that are meant to help users interpret formulas to better understand the outputted chart.

Variable Name	Variable Symbol	Unit of Measurement	Description
Angular Frequency	Omega_dielec	Unitless	This variable represents the angular frequency of the applied electric field, and is a crucial factor in determining the frequency dependent dielectric properties of polar materials. DIELECTRIC_DIPOLAR_CONST_1929: ((Dielec_Const_low_freq-Dielec_Const_high_freq)/(1+**omega_dielec**^2*tau_relax_time^2))+ Dielec_Const_high_freq
Activity Coefficient	Gamma	Unitless	The activity coefficient to determine water activity, important for understanding thermodynamic properties and stability of water in materials. aw_water_solution (695): **gamma***mol_w
Apparent Viscosity	eta_a	Pa*s	Measures the resistance to flow in fluids expressed in Pascal-seconds.
Area	Area	m^2	Fundamental physical quantity represent product of length and width in a two-dimensional space. electrical_conductivity_general (558): (Length*I)/(**Area***Voltage)
Ash Mass Fraction	m_a	Unitless	The ash mass fraction, described by formula *kg ash / kg total mass*, represents the proportion of ash content in a material. critical membrane breakdown potential ():
beta_f	beta_f	1/Pa	Adiabatic compressibility of fructose, measured in reciprocal Pascals, indicating how the volume of fructose changes under pressure without heat.
beta_g	beta_g	1/Pa	Adiabatic compressibility of glucose, measured in reciprocal Pascals, indicating how the volume of fructose changes under pressure without heat.
beta_s	beta_s	1/Pa	Adiabatic compressibility of sucrose, measured in reciprocal Pascals, indicating how the volume of fructose changes under pressure without heat.
Bound Water Mass Fraction	m_bw	Unitless	The bound water mass fraction is the ratio of water that is physically/chemically bound within a material to the mass of the material and cannot move or evaporate.
Brix Degrees	Brix	Degrees (Brix)	Brix degrees measure the percentage of soluble solids in a liquid, like sugar, which is essential in determining sweetness concentration, viscosity, and consistency of beverages.
Change in Ice Mass	dICE	Kilogram	The change in ice mass measures the variation in the mass of ice within a material, crucial to calculating thermal properties, like specific heat, and phase transitions.

Change in Temperature	dT	Celsius	The change in temperature measures the variation in temperature within a substance, useful for calculating thermal properties and phase transitions.
Collision Integral	collision_integral	Unitless	The collision integral is used to calculate the diffusivity of gases and represents the effect of intermolecular collisions, important in predicting gas behavior under various conditions.
Collision Diameter	collision_diameter	Angstroms	The collision diameter measures the effective diameter of gas molecules during collisions, crucial for calculating gas diffusivity from its influence on the path and interaction between molecules.
Concentration	C	Unitless	Concentration of a solution representing the percentage of a solute by weight in the solution, critical in determining density, thermal conductivity, and diffusivity (low level formulas).
Concentration of hydrocolloid	C_hydrocolloid	%	The concentration of hydrocolloid represents the percentage of hydrocolloid in a mixture and determines electrical conductivity in materials.
Concentration of Water	C_water	% water	The concentration of water represents the percentage of water by weight in a solution, where higher water concentration typically increases water activity affecting stability and preservation.
Concentration Parameter Term at 25C	K_c_25	S/m %	The concentration parameter at 25 ºC, measured in Siemens per meter per percentage, quantifies the contribution of hydrocolloid concentration to the electrical conductivity of a solution at 25 ºC.
Concentration solid	C_s	%	The concentration of solids represents the percentage of solid content in a mixture, influencing texture and stability and determining viscosity and conducting of materials.
Consistency Coefficient	K_visc	N*s^(n_visc)/m^2	The consistency coefficient is a parameter of the viscosity power law model, measured in Newton-seconds to the power of the flow behavior index per square meter, quantifying the inherent thickness of fluid under shear.