Application of Lagrange’s interpolation on analysing flavonoid of tempe

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Abstract. Interpolation in one of numerical methods to find a value between some data series. Laboratory tests of flavonoid levels in tempe have produced a series of data. These data are pairs of data between isoflavone levels and fat levels, isoflavone levels and protein levels, and also isoflavone levels and carbohydrate levels. However, to analyse the relationship between these data is difficult to do with regression. Lagrange's interpolation is an alternative method to see the relationship between a series of flavonoid data. From the three data can be generated quadratic equations that describe the relationship of the data. From these equations, we can estimate the level of isoflavone if the fat levels is known, as well as the protein levels and the carbohydrate levels.

1. Introduction
There are various methods that can be used to analysing some data to determine the relationship between two things, one of which is interpolation. Interpolation is a method to estimate intermediate values between precise data [1]. Lagrange polynomial is one of polynomial that already known for interpolation. Some problem has been solved by Lagrange's Interpolation. For example solving transportation with Lagrange’s interpolation [2]. On the other case one also using Lagrange’s interpolation for mobility prediction in ultra-dense [3]. In [4] Jana proposing Lagrange interpolation polynomial for reversible data hiding scheme. Combining with cipher feedback mode Lagrange’s interpolation can be used in multi-secret sharing scheme [5]. Some extended algorithm have been developed base on Lagrange’s interpolation such as in [6-7].

Tempe has been known as Indonesian traditional food. This food was made from soybean that fermented in specific condition. Even though traditional, some study have made to investigated the composition and nutrition in tempe. The pasteurization of hygienic tempe has been discussing in [8]. Influences of soybean variety and food processing to compare the content of bio-accessible folate, vitamin and isoflavones given in [9]. Some health benefits of tempe and the related product very well discussing on [10,11]. Flavonoid that found in several plants has potential antioxidant [12] and may protect cells from damage that leading to various disease such as cancer [13]. Soybean isoflavone has been observed as an chemopreventive breast cancer [14].

In this paper Lagrange's interpolation is discussed to see the mathematical relationship of substances contained in tempe with isoflavone in tempe. The content of tempe referred to in this paper is fibber, protein, fat, and carbohydrates.
2. Methods

2.1. Lagrange’s Interpolation
The general form of Lagrange polynomial degree of $-n$ can be written as follow:

$$P_n(x) = \sum_{i=0}^{n} a_i L_i(x) = a_0 L_0(x) + a_1 L_1(x) + \cdots + a_n L_n(x)$$

with

$$L_i(x) = \prod_{j=0}^{n} \frac{x - x_j}{x_i - x_j}$$

2.2. Tempe and Isoflavone
Tempe is a traditional Indonesian fermented food made from soybeans through fermentation by zygomycetes mushrooms especially Rhizopus Oligosporus [15]. Laboratorial analysis from nine sample of tempe giving data on Table 1:

| Sample | Isoflavone (%) | Fibber (%) | Protein (%) | Fat (%) | Carbohydrate (%) |
|--------|----------------|------------|-------------|---------|------------------|
| AB 1   | 6.63           | 17.33      | 44.22       | 23.89   | 5.46             |
| AB 2   | 6.52           | 25.91      | 40.78       | 18.47   | 5.15             |
| AB 3   | 6.78           | 22.50      | 40.86       | 13.09   | 15.67            |
| BB 1   | 6.88           | 28.29      | 40.43       | 14.85   | 8.29             |
| BB 2   | 7.00           | 13.55      | 39.95       | 17.20   | 20.53            |
| BB 3   | 7.00           | 17.96      | 38.39       | 20.92   | 21.5             |
| CB 1   | 3.31           | 21.62      | 36.98       | 11.87   | 20.83            |
| CB 2   | 6.02           | 23.98      | 36.79       | 9.98    | 20.47            |
| CB 3   | 6.96           | 10.33      | 38.56       | 20.57   | 20.53            |

Sample codes illustrating the resources of the samples. For example AB1, AB2 and AB3 are taken from the same resource, AB. We will analyse every three couple data from the same resource.

3. Results and Discussion
From every resource we build four polynomial Lagrange that analyzing fiber with isoflavone, protein with isoflavone, fat with isoflavone and carbohydrate with isoflavone.

3.1. Fiber and Isoflavone of Sample AB (Resource 1)
From sample AB we have three couple data of fibber and isoflavone

$$(x_0, y_0) = (17.33; 6.63)$$
$$(x_1, y_1) = (25.91; 6.52)$$
$$(x_2, y_2) = (22.50; 6.78)$$

Then we have Lagrange polynomial of degree-2

$$P_{AB}(x) = a_0 L_0 + a_1 L_1 + a_2 L_2$$

with
\[ L_0 = \frac{(x - x_1)(x - x_2)}{(x_0 - x_1)(x_0 - x_2)} = \frac{(x - 25.91)(x - 22.50)}{(17.33 - 25.91)(17.33 - 22.50)} = \frac{(x - 25.91)(x - 22.50)}{44.3586} = 0.02254x^2 - 1.09133x + 13.14232 \]
\[ L_1 = \frac{(x - x_0)(x - x_2)}{(x_1 - x_0)(x_1 - x_2)} = \frac{(x - 17.33)(x - 22.50)}{(25.91 - 17.33)(25.91 - 22.50)} = \frac{(x - 17.33)(x - 22.50)}{29.2578} = 0.03417x^2 - 1.36135x + 13.32722 \]
\[ L_2 = \frac{(x - x_0)(x - x_1)}{(x_2 - x_0)(x_2 - x_1)} = \frac{(x - 17.33)(x - 25.91)}{(22.50 - 17.33)(22.50 - 25.91)} = \frac{(x - 17.33)(x - 25.91)}{-17.6297} = -0.05672x^2 + 2.452679x - 25.4695 \]

So we got:
\[ P_{AB}(x) = a_0L_0 + a_1L_1 + a_2L_2 \]
\[ P_{AB}(x) = 6.63L_0 + 6.52L_1 + 6.78L_2 \]
\[ P_{AB}(x) = 6.63(0.02254x^2 - 1.09133x + 13.14232) + 6.52(0.03417x^2 - 1.36135x + 13.32722) + 6.78(-0.05672x^2 + 2.452679x - 25.4695) \]
\[ P_{AB}(x) = (0.14946x^2 - 7.23554x + 87.13359) + (0.22284x^2 - 8.87597x + 86.89344) + (-0.38457x^2 + 16.62916x - 172.68346) \]
\[ P_{AB}(x) = -0.01226x^2 + 0.51764x + 1.34357 \]

Graphic of this polynomial given in Figure 1.

Figure 1. The relation between fiber and isoflavone from sample AB

With an analogue procedure, from three couple data of protein and isoflavone we we got polynomial that describe relation between those two component as follow:
\[ Q_{AB}(x) = -0.95774x^2 + 81.4403x - 1721.8775 \]

Also for three couple data of fat and isoflavone we got:
\[ R_{AB}(x) = 0.00635x^2 - 0.24885x + 8.948804 \]

And for three couple data of carbohydrate and isoflavone giving result:
\[ S_{AB}(x) = -0.03233x^2 + 0.69789x + 3.78339 \]
3.2. Analysing of Sample BB (Resource 2)
Next from sample BB we also do the same procedure then we got four polynomial of degree-2 as follows:

\[ P_{BB}(x) = -0.00079x^2 + 0.024833x + 6.808209 \]
\[ Q_{BB}(x) = -0.12253x^2 + 9.60049x - 180.951 \]
\[ R_{BB}(x) = -0.00841x^2 + 0.320684x + 3.97298 \]
\[ S_{BB}(x) = -0.00074x^2 + 0.031193x + 6.67241 \]

3.3. Analysing of Sample CB (Resource 3)
Finally from sample CB we got:

\[ P_{CB}(x) = 0.10781x^2 - 3.76781x + 34.37772 \]
\[ Q_{CB}(x) = 9.36343x^2 - 705.004x + 13269.66 \]
\[ R_{CB}(x) = 0.175014x^2 - 5.25793x + 41.06261 \]
\[ S_{CB}(x) = -77.3148x^2 + 3185.574x - 32806.2 \]

4. Conclusion
From each resource we got four polynomial of degree 2 that describing relation between fiber-isoflavone, protein-isoflavone, fat-isoflavone and carbohydrate-isoflavone. For fiber-isoflavone and also protein-isoflavone, from sample AB and BB we got polynomial with negative coefficient on square term. It means that at first percentage of isoflavone increasing until maximum point than decreasing. But from sample CB we got positive coefficient on square term that means contrary, decreasing at first until minimum point then increasing. For fat-isoflavone, analysis of sample AB and CB giving positive coefficient on square term, but giving negative coefficient on sample BB. Otherwise for carbohydrate-isoflavone all of samples having same behavior. Different result probably caused by different process on making tempe. The processes including soybean type (local soybean or import soybean), time of soybean soaking (12 hours or more than that) and soybean heating (once or twice).

Sample AB and BB given once heating process while sample CB given twice heating process. Sample AB and CB made from import soybean while sample BB local soybean. And all samples are given 12 hours of soybean soaking. So probably relation of fiber-isoflavone and protein-isoflavone influences by heating process, fat-isoflavone influence by type of soybean, and carbohydrate-isoflavone influence by soybean soaking process.

Theoretically, on interpolation the more data will give the more accurate result. We can compare by analyzing more data that have same characteristic, than making validation by laboratory analysis.

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