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JUSTIFICATION OF THE EGG SORTING ALGORITHM BY CATEGORY BASED ON THE METHOD OF FUZZY SETS [13]

Aidar Moldazhanov, PhD
Department of Energy Saving and Automation,
Kazakh National Agrarian Research University
Tel.: +7 7082760127
E-mail: Aidar.m.k@ya.ru

Prof. Jakhfer Alikhanov, candidate of technical sciences
Department of Energy Saving and Automation,
Kazakh National Agrarian Research University
Tel.: +7 7773156598
E-mail: alikhanov.d@list.ru

Akmaral Kulmakhambetova
Department of Energy Saving and Automation,
Kazakh National Agrarian Research University
Tel.: +7 7072760769
E-mail: Akmaral.t.k@ya.ru

Azimzhan Azizov
Department of Energy Saving and Automation,
Kazakh National Agrarian Research University
Tel.: +7 7081115163
E-mail: Azizov811@mail.ru

Zinchenko Dmitry
Department of Energy Saving and Automation,
Kazakh National Agrarian Research University
Tel.: +7 7071712212
E-mail: Bolweviak@gmail.com

Prof. Plamen Daskalov, PhD
Department of Automatics and Mechatronics,
"AngelKanchev" UniversityofRuse
Tel.: +359 82 888 668
E-mail: daskalov@uni-ruse.bg

Abstract: *The article discusses the indicators of sorting eggs into categories by shape, density and weight and determined conditions for dividing eggs into categories based on methods of fuzzy logic. an algorithm was developed for sorting eggs into categories using the rules of fuzzy sets and the results of an experimental verification of the algorithmand is presented.*

Keywords: *egg, mass, density, shape, fuzzy logic, function, set, algorithm.*
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INTRODUCTION

In the modern world, eggs are one of the main components of the human diet, as they have a high level of protein and fat, carbohydrates, minerals and water. The use of eggs is widespread in food products, eggs are accepted both in natural form and in the form of components of various bakery and confectionery products. Therefore, the determination of the quality indicators of eggs is the main task in their production and sale. The main indicators of the quality of a whole egg are mass, density and shape. According to these indicators, eggs are divided into different categories. The eggs are sorted into categories according to GOST according to clear boundary conditions. However, the principle of sorting eggs according to clear logic has several disadvantages. Uncertainty arises due to errors in the determination of the sorting parameter at the border of division into categories. An egg weighing, for example, 63 grams differs little from an egg weighing 64 grams, although according to the standard they belong to different categories and, accordingly, have different selling prices. The method and mechanism for determining the mass have their own errors, which introduce uncertainty in the division of eggs into categories.

The question arises of how to create an intelligent system that, without human intervention, would control the egg quality indicators and make a decision on whether a given egg belongs to certain categories. What to do when managing devices requires blurry, rather than strictly defined boundaries. After all, an intelligent system means determining a state, and not just giving a result. When sorting objects such as eggs with indistinct division boundaries into categories, it is necessary that the system itself be able to evaluate to which category it is better to classify a given egg. In such cases, it is rational to use fuzzy logic algorithms. The advantage of using fuzzy controllers is that it becomes possible to build an automatic control system, in cases where there is only a qualitative characteristic of the object [1].

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EXPOSITION

There are various algorithms for fuzzy inference such as those of Mamdani, Larsen, Tsukamoto, etc. Наиболее распространенным из них является алгоритм Мамдани, который был взят за основу в данной работе [2, 3]. To select a regulator, fuzzification of values was performed and membership functions (trapezoidal) were constructed.

Since, in the standards for edible and hatching eggs, not one quality indicator is considered, but several indicators that are related to each other, the quality of the egg should be considered in aggregate according to the following parameters: egg mass (m), egg shape (form factor K1 and shape index K2), egg density (ρ). Therefore, the general linguistic rule for the egg sorting algorithm for a fuzzy set would look like this:

1. If the value of the shape factor (K2) and the shape index (K1) correspond to the intervals of standard values, then it is a conditioned egg.
2. If the egg meets the specified density values according to the requirements of the standard, then the egg is conditioned
3. If Mass has a membership range (X1-X2) and area has a membership range (X1-X2), then the category is Kn.

На основе этого был рассчитан индекс формы относительно трапециевидной функции по следующей формуле:

$$MF(\mathrm{x}) = \begin{cases} 1 - \dfrac{z - x}{z - y}. & if\ y \le x \le z; \\ 1. & if\ z \le x \le w; \\ 1 - \dfrac{x - w}{t - w}. & if\ w \le x \le t; \\ 0, & in\ other\ cases; \end{cases} \quad (1)$$

For each case, the probability values are obtained and a graph is plotted. Figure 1 shows a graph of the trapezoidal distribution function of eggs by the value of the shape index (K1)

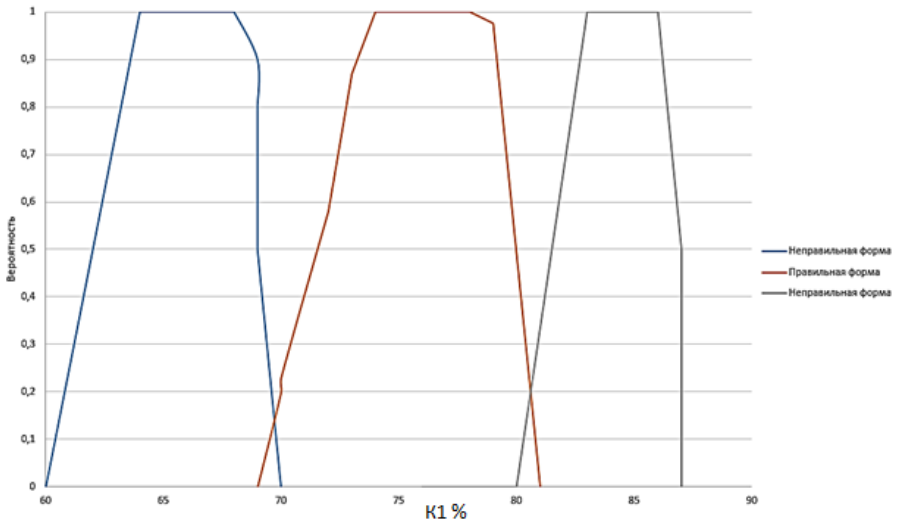

Figure 1. Graph of the trapezoidal distribution function of eggs by the value of the shape index (K1)

In a similar way, the membership function for the shape coefficient K2 was calculated, equal to the ratio of the square of the perimeter of the longitudinal section of the egg to its area, and a distribution graph was obtained, Figure 2.

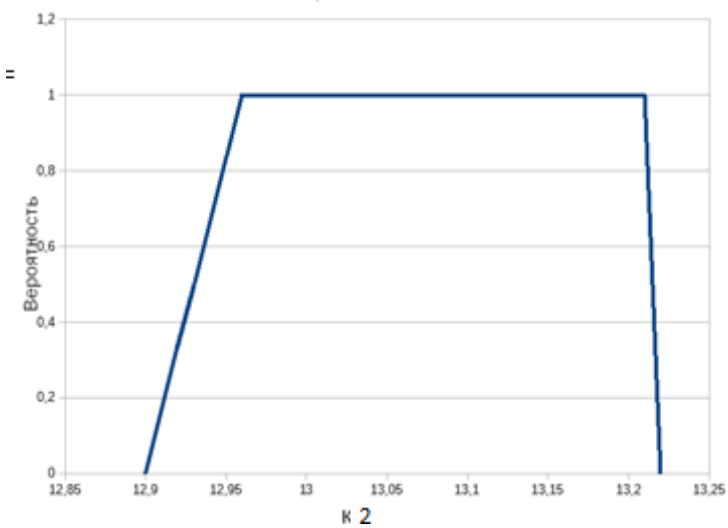

Figure 2. Graph of the trapezoidal distribution function of eggs by the value of the shape factor (K2)

Further, on the basis of GOST and experimental data, fuzzification and blurring of boundaries for the categories of eggs by weight and area were performed, Figure 3 and 4.

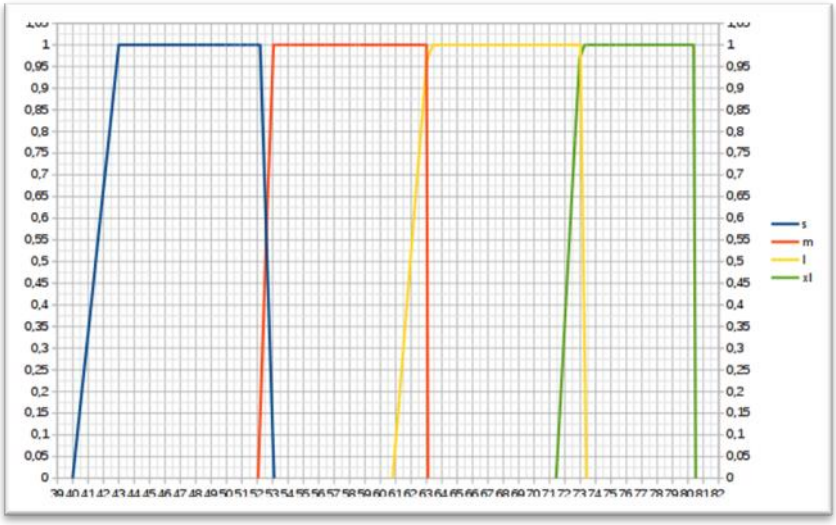

Figure 3. Graphs of trapezoidal functions, depending on the mass of eggs

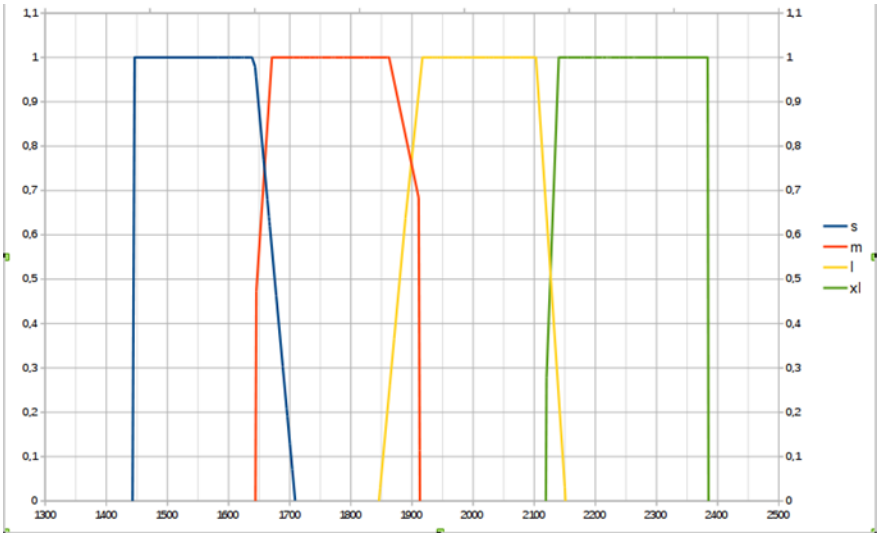

Figure 4. Trapezoidal distribution functions of the eggs area

According to the data obtained, the following rules have been developed for eggs when dividing into categories by shape:

1. If M (K1) belongs to the category of correct eggs with a probability greater than 0.77 and M (K2) with a probability greater than 0.57, then the egg belongs to the correct category.
2. If M (K1)) <= 70% AND M (K1) belongs to the category of incorrect eggs with a probability greater than 0.23 OR M (K2) <= 12.96 AND M (K2) belongs to the category of incorrect eggs with a probability greater than 0.43, then the egg is in the wrong category
3. 3. If M (K2))> = 80% AND M (K1) belongs to the category of incorrect eggs with a probability of more than 0.23 OR M (K2)> = 13.23 AND M (K2) belongs to the category of incorrect eggs with a probability of more than 0.13 , then the egg is in the wrong category.

Similarly, based on the distribution probabilities, rules have been developed for dividing eggs into categories by mass and area:

1. If MF (mS) belongs to the K_S category by mass with a probability> = 0.65 AND MF (sS)) with an area probability> 0.71 OR MF (K_S) == 1, then the egg belongs to the K_S category
2. If MF (mM) belongs to the category K_M by mass with a probability> = 0.45 AND MF (sM)) with a probability by area greater than> 0.75 OR MF (K_M) == 1 OR MF (K_M)> MF (K_L) THEN the egg belongs to category K_M

3. If MF (mL) belongs to the K_L category by mass with a probability> = 0.75 AND MF (sL)) with an area probability greater than> 0.5 OR MF (K_L) == 1 OR MF (K_L)> MF (K_XL) THEN the egg belongs to category K_L

4. If MF (mK_XL) belongs to the K_L category by mass with a probability> = 0.45 AND MF (sK_XL)) with a greater than 0.5 area probability OR MF (K_XL) == 1, then the egg belongs to the K_XL category

5. If the membership function is less than 0, then the egg belongs to deffect by weight, like an egg weighing less than the specified minimum value, if greater than 1, then the deffect by weight is greater than the specified maximum weight. Based on the formulated rules, an algorithm for sorting eggs into categories according to fuzzy logic was developed, which is shown in Figure 5.

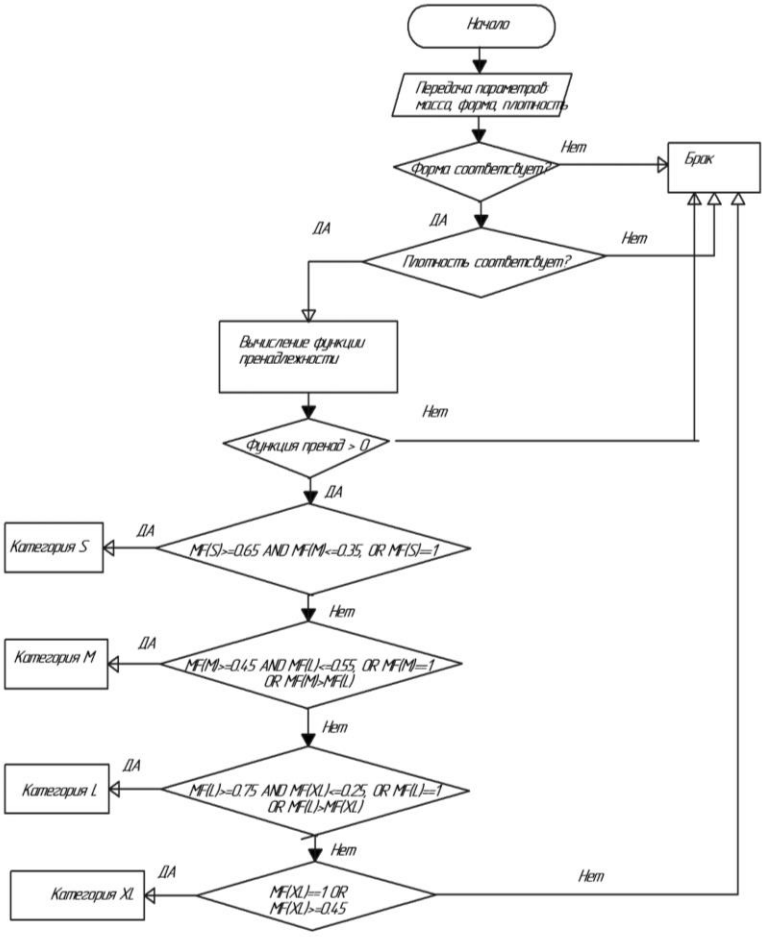

Figure 5 - Algorithm for sorting eggs into categories using fuzzy logic.

It should be borne in mind that in fuzzy logic 1 is true and 0 is false. Naturally, the closer to 1 the value of the trapezoidal function is, the closer it is to the truth, in accordance with this statement, and a decision is made on whether the egg belongs to one category or another.

Based on the calculated trapezoidal distribution function and the constructed algorithm, a repeated analysis of 80 eggs examined in the algorithm with a clear separation of eggs was carried out [4].

It was found that instead of 15 eggs classified as substandard in the algorithm with clear logic, in the algorithm with fuzzy logic based on two parameters K1 and K2, only 11 eggs are determined substandard in shape. These eggs are scrapped according to the algorithm. Figure 6 shows an example for an egg whose shape index is 69.82%, which in the algorithm with clear logic is a deffect, since K1 is less than 70%, and in the algorithm with fuzzy logic it is classified as conditional.

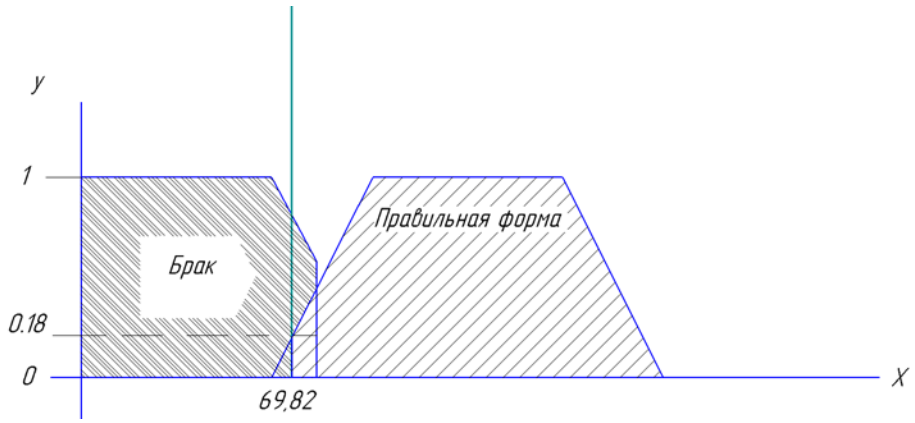

Figure 6 - Distribution function for an egg with a K1 shape index of 69.82%

According to the obtained value, the probability of an egg falling into a deffect by shape is 0.18, which according to the rule is less than 0.23, then the egg belongs to the category of eggs with the correct shape.

Similarly, the calculation was carried out for the shape coefficient K2, so the membership function of a given egg by K2 was distributed as follows:

$$K2 = 13.21, \qquad MF(K2\ rights) = 0.89 \tag{2}$$

In this case, two rules are observed, according to clear boundaries for K2, the shape factor should be less than 13.23.

The probability of distribution of the egg by the form factor to the correct eggs MF (K2 rights) is 0.89, while belonging to the wrong ones is 1-0.89 = 0.11 and according to the linguistic rule it is less than 0.18, THEN the egg belongs to the correct category forms. The distribution graph is shown in Figure 7.

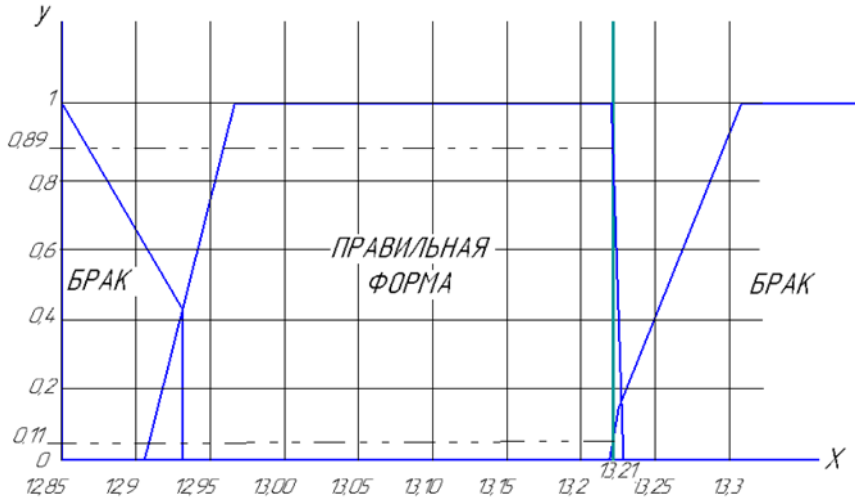

Figure 7. - Distribution function for an egg with a shape factor K2 equal to 13.21.

Further, for the remaining 69 eggs, the membership was calculated by mass and area according to the obtained rules, the distribution of which turned out as follows: defective eggs by weight less than 43 grams - 1 egg, category K_S - 13 eggs, category M - 18 eggs, category K_L - 24 eggs, category K_XL - 13 eggs and 0 egg shape rejects with a mass of more than 83 grams.

Consider the same example for the trapezoidal functions for an egg that is on the 62.75 gram border. Let's calculate membership functions for each category:

$$MF(S) = 0 \;\; MF(M) = 0.392 \;\; MF(L) = 0.94 \text{ и } \; MF(XL) = 0 \tag{3}$$

As can be seen from the obtained values, an egg with a mass of 82.75 with a probability of 0.94 belongs to the category K_L.

Based on the data obtained, we can conclude that the classification of eggs on the basis of fuzzy logic, in comparison with the classification according to the rules of clear logic, based on the determination of several parameters of the egg (mass, area, perimeter large and small diameter) gives a more objective classification based on human logic.

CONCLUSION

An algorithm for sorting eggs based on clear logic ensures the division of eggs into categories according to shape, weight and density in accordance with the requirements of the standard. According to the researches carried out, it can be established that for eggs, both in shape and in weight, they have clear classification boundaries. Eggs that are at the boundary between categories are often in the wrong category, unlike human expert judgment.

The developed algorithm of the automated information-measuring optical-electronic installation and the rules for the classification of eggs on the basis of fuzzy logic provides for the division of eggs into categories by shape and weight using two separation signs. To determine the shape of the egg, the values of the index and the shape factor are used, and to estimate the mass, the values of the mass and the sectional area of the image of the egg, which provides an objective assessment of egg quality indicators.

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