A New Unbalanced Linguistic Scale for the Classification of Olive Oil Based on the Fuzzy Linguistic Approach

M. Espinilla, F. J. Estrella and L. Martínez

Abstract A key factor that determines the price of olive oil is its sensory profile. The International Olive Council (IOC) establishes four quality categories and a method to classify a sample of olive oil into one category, depending on its sensory characteristics. To do so, a taster panel is rigorously trained to provide the intensity perceived on a 10-cm scale for each organoleptic characteristic. These intensities are aggregated and analyzed statistically to obtain the classification among one of four quality categories established. The modeling and management of perceptions in sensory evaluation processes is an important problem because the information acquired by human senses always involves imprecision and uncertainty that has a non-probabilistic nature. The application of the fuzzy linguistic approach to sensory evaluation processes can model and manage the uncertainty and vagueness of this kind of processes. The main challenge in this approach is to establish a linguistic scale to measure tasters' perceptions, since the success or failure of the sensory evaluation process will depend on the definition of a proper scale. In this contribution is analyzed and proposed an unbalanced linguistic scale to carry out the classification of olive oil samples, such a scale is validated, conducting a sensory evaluation case study for olive oil.

Keywords Sensory evaluation · Fuzzy linguistic approach · Unbalanced linguistic scale · Olive oil · Linguistic 2-tuple.

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1 Introduction

Sensory evaluation is an evaluation discipline in which the information provided by a panel of individuals is perceived by human senses of *sight, smell, taste, touch, and hearing*. This evaluation is generally applied to the quality assurance for products, to solve conflicts between customers and producers, to develop new products, and to exploit new markets adapted to the consumer's preference [1, 2].

The sensory information like color, flavor, taste, and mouthfeel are generally obtained through subjective information (perceptions). This fact implies the following main difficulties in sensory evaluation processes:

- $D1$: The information presented in a sensory evaluation process always implies uncertainty and imprecision which are generally analyzed statistically, assuming that any uncertainty can be represented by a probabilistic distribution. However, this information has a non-probabilistic nature [3].
- $D2$: One key issue for the success of a sensory evaluation process depends on the correct definition of the scale used to measure the sensory information. This definition is not trivial because it requires to fix the structure of the scale, the number of the terms, its distribution, etc.

Researches have shown that the fuzzy linguistic approach [4] and the fuzzy set theory [5] are considered useful tools to model and manage the uncertainty in sensory evaluation processes of many products [3, 6, 7] like mango drink [8], tea [9], coffee [10], sausages [11], or Indian yogurt [12]. So, the proposed linguistic sensory evaluation model [13] for olive oil overcomes the first difficulty, by using the fuzzy linguistic approach [4] to model and manage such an uncertainty.

In this contribution, we are focused on the quality of olive oil because this is a key factor in its marketing: *an excellent quality implies a higher price in the market* [14, 15]. The quality of a sample of olive oil is established by its sensory profile in which each sensory attribute (positive or negative) is measured by a trained tasters' panel. The International Olive Council (IOC) establishes four quality categories for the olive oil: *virgin extra*, *virgin*, *ordinary*, and *lampante* and fixes the procedure to assess the organoleptic characteristics and classify the olive oil on the basis of these characteristics. So, each taster provides the intensity perceived of each attribute on a 10-cm scale in a profile sheet. The olive oil is categorized, taking into account the median value of the negative attributes and the median for the fruity attribute (positive attribute), according to reference ranges: 0, 3.5, and 6. A detailed description about the procedure and attributes can be found in IOC/T.20/Doc. No 15/Rev. November 4, 2011.[1]

In a previous work, [13] was proposed a linguistic sensory evaluation model to establish the category of a sample of olive oil, dealing with an unbalanced linguistic scale [16, 17]. The scale proposed was a five-term scale whose distributions were defined according to the reference ranges to classify the olive oil. However,

[1] www.internationaloliveoil.org/documents/viewfile/3685-orga6

recently, we have detected that such an unbalanced linguistic scale fails in the difficulty *D2* because samples of olive oil are classified incorrectly when olive oils are doubtful between two categories.

The aim of this contribution is to analyze with two taster panels of olive oil an adequate unbalanced linguistic scale and then to validate it, carrying out a sensory evaluation case study for a set of samples of olive oil, belonging to different categories.

The rest of the contribution is set out as follows. Section 2 reviews some linguistic concepts necessary to understand our proposal. Section 3 introduces in short the unbalanced linguistic sensory evaluation model utilized in our sensory evaluation case study. Section 4 presents in detail the proposal of the unbalanced linguistic scale and its validation, carrying out a sensory evaluation case study. Finally, in Sect. 5, conclusions are drawn.

2 Linguistic Background

Due to the use of linguistic information and processes of computing with words [18] in the olive oil evaluation, here we review some concepts used.

2.1 Fuzzy Linguistic Approach

Sensory information is the information perceived by the human senses of *sight, smell, taste, touch, and hearing*. This information implies uncertainty, vagueness, and imprecision, and the use of the fuzzy linguistic approach [4] has provided successful results modeling this kind of information. The fuzzy linguistic approach represents this information as linguistic values by means of linguistic variables [4]. Usually, in these cases, it is required that in the linguistic term set, there exist:

1. A negation operator: $\mathrm{Neg}(s_i) = s_j$ such that $j = g - i$ ($g + 1$ is the cardinality).
2. An order: $s_i \leq s_j \Longleftrightarrow i \leq j$. Therefore, there exists a *min* operator and a *max* operator.

The semantics of the terms are given by fuzzy numbers defined in the [0,1] interval, which are usually described by membership functions.

2.2 2-Tuple Linguistic Representation Model

The use of linguistic information implies to operate with such a type of information, that is, processes of computing with words (CWs). In [19] was presented a linguistic representation model based on linguistic 2-tuples that carries out

processes of CW in a precise way when the linguistic term sets are symmetrical and uniformly distributed.

The linguistic 2-tuple representation model is based on the concept of *symbolic translation* [19] and represents the linguistic information through a 2-tuple (s, α), where $s \in S = \{s_0, \ldots, s_g\}$ is a linguistic term and α is a numerical value representation of the symbolic translation [19]. Thereby, being $\beta \in [0, g]$ the value generated by a symbolic aggregation operation, we can assign a 2-tuple (s, α) that expresses the equivalent information of that given by β.

Definition 1 [19]. Let $S = \{s_0, \ldots, s_g\}$ be a set of linguistic terms. The 2-*tuple set associated with* S is defined as $\langle S \rangle = S \times [-0.5, 0.5)$. We define the function $\Delta_S : [0, g] \longrightarrow \langle S \rangle$ given by

$$\Delta_S(\beta) = (s_i, \alpha), \text{ with } \begin{cases} i = \text{ round } (\beta), \\ \alpha = \beta - i, \end{cases} \tag{1}$$

where *round* assigns to β the integer number $i \in \{0, 1, \ldots, g\}$ closest to β.

We note that Δ_S is bijective [19], and $\Delta_S^{-1} : \langle S \rangle \longrightarrow [0, g]$ is defined by $\Delta_S^{-1}(s_i, \alpha) = i + \alpha$. In this way, the 2-tuples of $\langle S \rangle$ will be identified with the numerical values in the interval $[0, g]$.

The linguistic 2-tuple representation model has a linguistic computing model associated that accomplishes CW processes in a precise way. Different aggregation operators have been proposed for linguistic 2-tuple [19–22]. In our proposal, we will use the median aggregation operator for linguistic 2-tuple since the IOC computes collective sensory intensities based on the calculation of their medians.

Definition 2 [13]. Let $((s_1, \alpha), \ldots, (s_n, \alpha)) \in \langle S \rangle^n$ be a vector of linguistic 2-tuples. The 2-*tuple median operator* is the function $\text{Med} : \langle S \rangle^n \longrightarrow \langle S \rangle$ defined by if *is odd*

$$\text{Med } \big((s_1, \alpha), \ldots, (s_n, \alpha)\big) = (s_i, \alpha)$$

if *n is even*

$$\text{Med } \big((s_1, \alpha), \ldots, (s_n, \alpha)\big) = \Delta_S\left(\frac{\Delta_S^{-1}(s_i, \alpha) + \Delta_S^{-1}(s_{i+1}, \alpha)}{2}\right)$$

where (s_i, α) is the round$(\frac{n}{2})$th largest element of $\langle S \rangle^n$.

3 Unbalanced Linguistic Sensory Evaluation Model

The aim of this contribution is to propose a new and adequate unbalanced linguistic scale to carry out the classification of olive oil, taking into account the nature of the uncertainty in sensory evaluation processes. The proposed scale will

be validated by using the linguistic sensory evaluation model proposed in [13] based on fuzzy linguistic approach. In this section, we point out general features of this model and describe its phases.

The unbalanced linguistic sensory evaluation model is a good option in the sensory evaluation process of olive oil because the references ranges for classifying the olive oil are not symmetrical in the method proposed by IOC and this model offers a scale with different levels of discrimination on both sides to express the tasters' perceptions. Unlike the classical quantitative IOC method, the unbalanced linguistic sensory evaluation model does not need some statistical analysis because the fuzzy linguistic semantics manage the uncertainty involved in the tasters' perceptions. Despite this, it is noteworthy that the linguistic aggregation operator to compute the collective intensity for each sensory attribute and the reference ranges of intensities to classify the samples of olive oil are equivalent to the quantitative method proposed by IOC.

The linguistic sensory evaluation model with an unbalanced linguistic terms set consists of the following phases: evaluation framework, gathering sensory information, and rating samples [13]. These are described in the following subsections.

3.1 Evaluation Framework

It defines the structure of the sensory evaluation process: the set of tasters, the set of samples of olive oil that will be evaluated and, finally, the unbalanced linguistic scale in which tasters' perceptions will be expressed.

In order to define this scale, it is necessary to set its number of terms, its syntaxis, and its distribution. The semantic of each term is calculated with the algorithm proposed in [16] to build the semantics for an unbalanced linguistic terms set, using a linguistic hierarchy (LH) [23] and the linguistic 2-tuples representation model [19] (a detailed description about the algorithm can be found in [16]). So, the algorithm provides a *hierarchical semantic representation* $LH(S)$ for an unbalanced linguistic terms set $\mathcal{S} = \{s_i, \quad i = 0, \ldots, g\}$ and obtains its representation in a LH.

Finally, in the evaluation framework, it is necessary to transform the reference ranges to classify the sample of olive oil into linguistic 2-tuples in the unbalanced linguistic scale.

3.2 Gathering Sensory Information

Once the framework has been defined to evaluate the set of samples of olive oil, the sensory information must be provided by the taster panel. In a profile sheet with the unbalanced linguistic scale fixed in the evaluation framework, each taster provides the intensity perceived about each sensory characteristic.

3.3 Rating Samples

This phase computes a collective intensity for each sensory attribute in order to classify each sample of olive oil, according to the perceived intensities. Due to the fact that the sensory evaluation model manages information expressed in an unbalanced linguistic scale, it is necessary to accomplish CW processes with this type of information. To do so, this linguistic sensory evaluation model uses the computational model for unbalanced linguistic term set presented in [16, 17] to compute the collective intensity for each sensory attribute. According to the collective intensity of the fruity attribute and the collective intensity of the defect perceived with the greatest intensity (negative attributes), as well as the reference ranges, each sample of olive oil is classified among one of four quality categories established: *virgin extra*, *virgin*, *ordinary*, and *lampante*.

4 New Unbalanced Linguistic Scale to Classify Olive Oil Samples

In this section, we present the analysis carried out with two taster panels of olive oil to propose an adequate unbalanced linguistic scale to classify a sample of olive oil. We then present the validation of the proposed scale, carrying out a sensory evaluation case study for a set of 30 samples of olive oil. Finally, we analyze and discuss the results.

4.1 New Proposed Unbalanced Linguistic Scale

In order to analyze and define an unbalanced linguistic scale, we selected two taster panels composed of 6 women and 10 men between 22 and 55 years old, being 16 tasters and 2 panel leaders. Both taster panels are accredited by OIC from 2008. The scale initially proposed (see Fig. 1a) in the unbalanced linguistic sensory evaluation model [13] is shown to the taster panels in order to analyze it and to propose a better alternative. After several meetings with panels, they agreed that 5 is an insufficient number of labels to measure tasters' perceptions in order to classify doubtful samples between two categories.

To overcome such a limitation, they propose an unbalanced linguistic scale with 7 linguistic terms. The distribution of the proposed scale is as follows: a central linguistic term, four terms on the left side, and two terms on the right side. The syntax provided for the panels and the semantic obtained for the algorithm to build the semantic for an unbalanced linguistic scale are illustrated in Fig. 1b.

Once the tasters had defined the unbalanced linguistic scale and their semantics were computed [16], it is necessary to transform the reference ranges proposed by

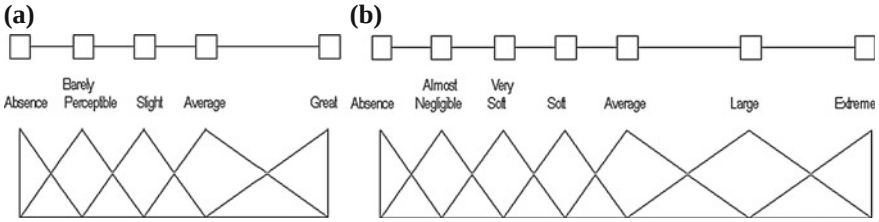

Fig. 1 **a** Initial linguistic scale **b** New proposed linguistic scale

IOC into linguistic 2-tuple on the unbalanced linguistic scale to classify the olive oil. The reference ranges expressed in linguistic 2-tuple to classify the olive oil are shown in the Table 1.

4.2 Procedure to Validate the Proposed Scale

In order to validate the proposed unbalanced linguistic scale, we conducted a sensory evaluation case study for 30 samples of olive oil, belonging to different categories, using the unbalanced linguistic sensory evaluation model, reviewed in Sect. 3.

The set of samples of olive oil were established with different profiles that included samples clearly pre-classified as one category and samples doubtful between two categories. The set of samples and their profiles were the following:

- 3 Extra Virgin (E1, E2, E3)
- 3 Extra Virgin (doubtful with Virgin) (EV1, EV2, EV3)
- 3 Virgin (doubtful with Extra Virgin) (VE1, VE2, VE3)
- 3 Virgin (V1, V2, V3)
- 3 Virgin (doubtful with Ordinary) (VO1, VO2, VO3)
- 3 Ordinary (doubtful with Virgin) (OV1, OV2, OV3)
- 3 Ordinary (O1, O2, O3)
- 3 Ordinary (doubtful with Lampante) (OL1, OL2, OL3)
- 3 Lampante (doubtful with Ordinary) (LO1, LO2, LO3)
- 3 Lampante (L1, L2, L3)

Table 1 Classification of olive oil

	Median defects (Med-n)	Median fruity (Med-f)
Extra virgin	Med-n=(absence, 0)	Med-f > (absence, 0)
Virgin	Med-n=(absence, 0)	Med-f=(absence, 0)
Virgin	(absence, 0) < Med-n ≤ (soft, 0)	
Ordinary	(soft, 0) < Med-n ≤ (average, 0.4)	
Lampante	(average, 0.4) < Med-n	

During the 2012 campaign of olive oil, the two panel leaders tasted different samples, of which 30 were selected according to the set of established profiles. Once the samples were selected, the sensory evaluation process began in order to validate the new proposed unbalanced linguistic scale. The sensory evaluation case study took place during seven weeks and was carried out following the test conditions and standards fixed by the method proposed by IOC.[2]

In the first week, two taster panels were trained in the unbalanced linguistic sensory evaluation model with the new proposed unbalanced linguistic scale shown in Fig. 1b.

During the next three weeks, each sample of olive oil was analyzed by a taster panel using the unbalanced linguistic sensory evaluation model. The set of 30 unidentified samples were distributed between the two taster panels. In a week, two tasting sessions were performed by each taster panel. Each taster panel analyzed among 2 and 4 samples of olive oil in each session.

In the last three weeks, in order to validate the classification obtained by the unbalanced linguistic sensory evaluation model, each taster panel tasted its samples by the IOC method. A comparative example of the sensory information and the classification obtained for the olive oil sample *EV*1 with the unbalanced linguistic sensory evaluation model (linguistic information) and the IOC method (numerical information) are shown in Table 2.

4.3 Results and Discuss

In this section, we analyze the results of the conducted sensory evaluation case study.

The classification of olive oil samples was carried out by a panel leader, according to intensities of defects and the fruity attribute, following the guidelines of the unbalanced linguistic sensory evaluation model.

For each sample of the set, the category provided by the unbalanced linguistic sensory evaluation model, using the new proposed unbalanced linguistic scale, matched with the category computed by IOC method, based on the statistical analysis. The classifications obtained for the set of 30 olive oil samples, using both models, are shown in Table 3. Furthermore, it is noteworthy that each category also coincided with the pre-classification offered by the panel leader.

In view of the results, the set of tasters, who participated in the case study, pointed out that the high precision level required by the quantitative IOC sensory model is unnecessary to assess sensory attributes because this precision is not required to correctly classify olive oil samples. Furthermore, generally, this high precision level implies a long-term training of tasters and, sometimes, frustrated tasters.

[2] IOC/T.20/Doc. No 5 "Glass for oil tasting."

Table 2 Sensory information about an evaluated sample of olive oil:EV1

Classification done by the panel leader: Extra Virgin (doubtful with Virgin)									
Classification with the unbalanced linguistic sensory evaluation model: Extra Virgin									
Taster	Fusty	Musty	Winey	Frostbitten	Rancid	Others	Fruity	Bitter	Pungent
A	Alm. Neg.	Abs.	Abs.	Abs.	Abs.	Abs.	Alm. Neg.	Alm. Neg.	Alm. Neg.
B	V. Soft	Abs.	Abs.	Abs.	Abs.	Abs.	V. Soft	Soft	Average
C	Alm. Neg.	Abs.	Abs.	Abs.	Abs.	Abs.	V. Soft	Alm. Neg.	Alm. Neg.
D	Abs.	Abs.	Abs.	Abs.	Abs.	Abs.	Soft	Soft	V. Soft
E	Abs.	Abs.	Abs.	Abs.	Abs.	Abs.	Soft	V. Soft	V. Soft
F	Abs.	Abs.	Abs.	Abs.	Abs.	Abs.	V. Soft	Soft	V. Soft
G	Abs.	Abs.	Abs.	Abs.	Abs.	Abs.	V. Soft	V. Soft	Soft
H	Abs.	Abs.	Abs.	Abs.	Abs.	Abs.	V. Soft	Alm. Neg.	Alm. Neg.
Median	(Abs.,0)	(Abs.,0)	(Abs.,0)	(Abs.,0)	(Abs.,0)	(Abs.,0)	(V. Soft,0)	(V. Soft,0)	(V. Soft,0)
Classification with the IOC method: Extra Virgin									
Taster	Fusty	Musty	Winey	Frostbitten	Rancid	Others	Fruity	Bitter	Pungent
A	0	0	0	0	0	0	2,7	2,7	4
B	0	0	0	0	0	0	3,3	3	3,4
C	1,7	0	0	0	0	0	3,2	2,3	2,7
D	0	0	0	0	0	0	4,1	3,5	2,1
E	0	0	0	0	0	0	3,7	1,6	2,7
F	0	0	0	0	0	0	3	1,7	2,5
G	0	1,4	0	0	0	0	3	2,9	4,2
H	2	0	0	0	0	0	2	2,8	2,9
Median	0,00	0,00	0,00	0,00	0,00	0,00	3,10	2,75	2,80

Table 3 Classification obtained with both models

	Linguistic model	OIC method
Extra virgin	E1, E2, E3, EV1, EV2, EV3	E1, E2, E3, EV1, EV2, EV3
Virgin	VE1, VE2, VE3, V1, V2, V3, VO1, VO2, VO3,	VE1, VE2, VE3, V1, V2, V3, VO1, VO2, VO3,
Ordinary	OV1, OV2, OV3, O1, O2, O3, OL1, OL2, OL3	OV1, OV2, OV3, O1, O2, O3, OL1, OL2, OL3
Lampante	LO1, LO2, LO3, L1, L2, L3	LO1, LO2, LO3, L1, L2, L3

Therefore, the results of the sensory evaluation case study are very satisfactory. The proposed unbalanced linguistic scale offers more flexibility to express perceptions, models and manages consistently the uncertainty and vagueness presented in sensory evaluation process, and provides the same classification as the IOC method based on the statistical analysis and the opinion of a panel leader.

5 Conclusions

The sensory evaluation is a process in which the uncertainty and vagueness are present because the involved information is based on the knowledge acquired via human senses. The use of linguistic information to model and manage such uncertainty is a suitable framework. One part of the success of a sensory evaluation process depends on the correct definition of the linguistic scale used to measure the sensory information. In this contribution, we have analyzed and proposed with two taster panels an unbalanced linguistic scale to classify a sample of olive oil in one category of the four categories of quality established by the IOC. The proposed unbalanced linguistic scale has been validated in a sensory evaluation case study, using an unbalanced linguistic sensory evaluation model based on the fuzzy linguistic approach, proposed in our previous research [13]. The main result of this case study is that the proposed unbalanced linguistic scale provides more flexibility to express the perceptions, offering the same classification as the method proposed by IOC based on statistical analysis.

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References

1. Dijksterhuis G (1997) Multivariate data analysis in sensory and consumer science. Food and Nutrition (Press Inc.), Trumbull, Connecticut, USA
2. Ruan D, Zeng X (eds) (2004) Intelligent sensory evaluation: methodologies and applications. Springer, New York
3. Martínez L (2007) Sensory evaluation based on linguistic decision analysis. Int. J. Approximate Reasoning 44(2):148–164
4. Zadeh L (1975) The concept of a linguistic variable and its applications to approximate reasoning. Inform Sci, Part I, II, III, vol 8, 9, pp 199–249, 301–357, 43–80
5. Zadeh L (1965) Fuzzy sets. Inform Control 8(3):338–353
6. Chen Y, Zeng X, Happiette M, Bruniaux P, Ng R, Yu W (2009) Optimisation of garment design using fuzzy logic and sensory evaluation techniques. Eng Appl Artif Intell 22(2):272–282
7. Perrot N, Ioannou I, Allais I, Curt C, Hossenlopp J, Trystram G (2006) Fuzzy concepts applied to food product quality control: a review. Fuzzy Sets Syst 157(9):1145–1154
8. Jaya S, Das H (2003) Sensory evaluation of mango drinks using fuzzy logic. J Sens Stud 18(2):163–176
9. Sinija V, Mishra H (2011) Fuzzy analysis of sensory data for quality evaluation and ranking of instant green tea powder and granules. Food Bioprocess Technol 4(3):408–416
10. Russo L, Albanese D, Siettos C, di Matteo M, Crescitelli S (2012) A neuro-fuzzy computational approach for multicriteria optimisation of the quality of espresso coffee by pod based on the extraction time, temperature and blend. Int J Food Sci Technol 47(4):837–846
11. Lee S, Kwon YA (2007) Study on fuzzy reasoning application for sensory evaluation of sausages. Food Control 18(7):811–816
12. Routray W, Mishra H (2012) Sensory evaluation of different drinks formulated from dahi (indian yogurt) powder using fuzzy logic. J Food Processing Preserv 36(1):1–10
13. Martínez L, Espinilla M, Liu J, Pérez L, Sánchez P (2009) An evaluation model with unbalanced linguistic information applied to olive oil sensory evaluation. J Multiple Valued Logic Soft Comput 15(2–3):229–251
14. Blery E, Sfetsiou E (2008) Marketing olive oil in Greece. Br Food J 110(11):1150–1162
15. de Graaff J, Duran Zuazo V-H, Jones N, Fleskens L (2008) Olive production systems on sloping land: prospects and scenarios. J Environ Manage 89(2):129–139
16. Herrera F, Herrera-Viedma E, Martínez L (2008) A fuzzy linguistic methodology to deal with unbalanced linguistic term sets. IEEE Trans Fuzzy Syst 16(2):354–370
17. Martínez L, Herrera F (2012) An overview on the 2-tuple linguistic model for computing with words in decision making: Extensions, applications and challenges. Inf Sci 207(1):1–18
18. Martínez L, Ruan D, Herrera F (2010) Computing with words in decision support systems: an overview on models and applications. Int J Comput Intell Syst 3(4):382–395
19. Herrera F, Martínez L (2000) A 2-tuple fuzzy linguistic representation model for computing with words. IEEE Trans Fuzzy Syst 8(6):746–752
20. Wei G (2011) Some harmonic aggregation operators with 2-tuple linguistic assessment information and their application to multiple attribute group decision making. Int J Uncertainty Fuzziness Knowl Based Syst 19(6):977–998
21. Xu Y, Wang H (2011) Approaches based on 2-tuple linguistic power aggregation operators for multiple attribute group decision making under linguistic environment. Appl Soft Comput J 11(5):3988–3997
22. Yang W, Chen Z (2012) New aggregation operators based on the choquet integral and 2-tuple linguistic information. Expert Syst Appl 39(3):2662–2668
23. Herrera F, Martínez L (2001) A model based on linguistic 2-tuples for dealing with multigranularity hierarchical linguistic contexts in multiexpert decision-making. IEEE Trans Syst Man Cybern B Cybern 31(2):227–234