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The role of marbling as an intrinsic characteristic at the point of meat purchase – the Taguchi approach

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Abstract. Meat quality is considered a complex concept depending on many characteristics that could be intrinsic or extrinsic. At the same time, intrinsic and extrinsic quality cues affect consumers' purchasing decisions. The importance of each quality cue was analysed and discussed in previous literature. Thus, colour and level of marbling of fresh meat were defined as key quality cues at the point of meat purchase. These characteristics are mostly related to pork and beef. The aim of this study was to identify quality characteristics that most closely match the consumer's preferences and at the same time could be related to quality losses. For that purpose, this paper gives a novel approach of the potential application of Taguchi loss function associated with quality characteristics and related losses for colour and level of marbling. This application can be implemented by providing a quality characteristic's proper target values and limits, which would make the meat production process more consistent.

1. Introduction

The concept of meat quality from a consumer perspective is defined in terms of the moment of quality evaluation. Quality expectation is formed by consumers at the purchase point, while experienced meat quality arises after preparation and at the moment of consumption. In addition, experienced quality is based on confirmation or rejection of the expectations [1]. Different moments of quality evaluation are related to different quality cues observed by consumers. These quality cues are in previous literature defined as intrinsic and extrinsic [2]. Typical intrinsic quality cues are based on the physical appearance of product like colour, fat content, texture, amount of drip, level of marbling etc. [1, 3-8]. Other types of intrinsic quality cues are experience and credence intrinsic characteristics [9]. Experience intrinsic quality characteristics comprise attributes observed at point of consumption such as flavour, leanness, juiciness, tenderness, taste, freshness etc. Credence intrinsic quality characteristics consist of credence attributes that are related to health and process benefits that could satisfy consumer's moral and ethical needs. Examples of credence intrinsic quality cues are healthiness of product and nutritional value [4, 10-13]. On the other hand, extrinsic quality cues are defined as product-related attributes for which consumers form first impressions at the point of purchase. Some extrinsic quality cues for meat are brand, price, packaging, place



of purchase, origin of the animal, breed, animal welfare, feeding system, environmental impact of the livestock production, and certification labels [5, 9, 11, 12, 14, 15].

However, consumers differently evaluate the importance of intrinsic quality cues for different types of meat (beef, pork, chicken and game meat). Basic intrinsic attributes of beef are meat colour, fat content and cut [1], but indispensable characteristics are fat marbling, amount of drip, texture, freshness, juiciness, tenderness, flavour, taste etc. When it comes to pork, the most important intrinsic quality cues are freshness, colour, smell, appearance, cut, fat distribution and meat-bone-fat ratio [16]. On the other hand, purchase of chicken meat in Serbia depends on three main attributes: colour, freshness and fat content [17, 18]. Finally, the most important intrinsic attributes of game meat examined by European consumers were texture, appearance and colour [19]. It is obvious that colour is recognized as one of the main intrinsic characteristics in every type of meat.

Meat colour is defined as a very important visible characteristic of considerable influence on consumers at the point of meat purchase [20]. Through consumers' perceived quality examination, it was shown that consumers preferred pinkish and light-coloured beef over darker beef [3, 6, 7]. Thus, it was confirmed that light red colour is an indicator for youthful and high quality meat. Since the first impression that consumers have of any meat product is colour, it is important to know how to measure and control this quality cue. Although many factors could influence meat colour and meat colour evaluation [21], there are several common instrumental colour analyses that have been used extensively for meat and meat products. Beside examples of using Minolta and Hunter branded colorimeters, many studies presented how to use computer vision system (CVS) for meat colour analysis, and use of this is increasing [22, 23].

When it comes to determining the quality of meat, marbling score is the dominant parameter. Definition of marbling score was provided in study of Shiranita et al., [24], as "measure of the distribution density of fat in the rib-eye region". It has been reported that a certain degree of marbling could affect juiciness, tenderness, palatability, and flavour of meat [25, 26]. In addition, marbling could directly affect a consumer's consumption decisions. Consequently, marbling as an influencing factor in the meat purchase decisions, has to be maintained and controlled. Many countries have developed methods and standards for evaluating the marbling degree of meat [25]. As is known, standard methods were used for visual appraisal of meat marbling. Although visual appraisal has been used by the industry for a long time, it is of subjective nature depending on experience and intuition of inspectors [24]. Therefore, the application of instrumental measurement techniques for automatizing the visual inspection of meat has been attracting considerable attention.

Nevertheless, imaging techniques, particularly CVS, have been extensively studied and considered as the most suitable technique for the objective grading of meat marbling [25]. Furthermore, the CVS method seemed to be suitable for evaluating the colour of different types of meat such as beef, pork, and chicken [27, 28] as well as meat products [22, 29]. Besides that, as a non-destructive and objective method, this system includes the possibility of analysing the surface of complex food matrixes such as processed meat products. The process of image analysis starts once the pictures of fresh meat or meat products are captured using appropriate computer software for image analyses of colour or marbling [30].

The objective of this paper is to give an overview of the potentials of using the Taguchi approach in defining quality function loss associated with marbling of pork and beef.

2. Taguchi method

Over the last decades, the relationship between the economics of production and quality has been subject of many studies and managerial topics. This relationship considers various approaches from reducing setup costs (and time) to improving process quality. Realizing that there are different types of losses and consistently striving to achieve a particular target of product quality, Taguchi established a new approach [31]. Its main aim was to avoid the concept of zero defects, which could encourage managers to set wider tolerances than necessary. The Taguchi method is a specific statistical technique for implementing robust processes in product design and improvement of product quality at a relatively low cost [32]. According to Taguchi, quality robustness stems from consistency in production. With that consistency, it is much easier to detect the noise (non-controllable) factors causing the quality variations. Thus, mentioned consistency is achievable with optimal process design – the best process settings to optimize multiple quality characteristics [32].

2.1. Taguchi loss function (TLF)

Main inputs for Taguchi loss function are measured values of particular quality characteristics and determined target values. Quality loss for a single product is proportional to the square of the deviation of the quality characteristic from its target value. This loss or cost was characterized by Taguchi as a quadratic function:

$$L(x) = k \cdot (x - \mu)^2 \quad (1)$$

where $L(x)$ is the loss per unit, k is Taguchi's loss parameter – a constant that depends on loss type, x is the actual value of the quality characteristic and μ is the target value. While k constant depends on loss value and type, structure of TLF depends on quality characteristic type [33]. Thus, there are different types of losses (related to manufacturer or consumer's dissatisfaction) and three different types of TLFs in terms of characteristic type. The first one is "the nominal value, the best value" which has curves with two-sided functions (Figures 1 and 2).

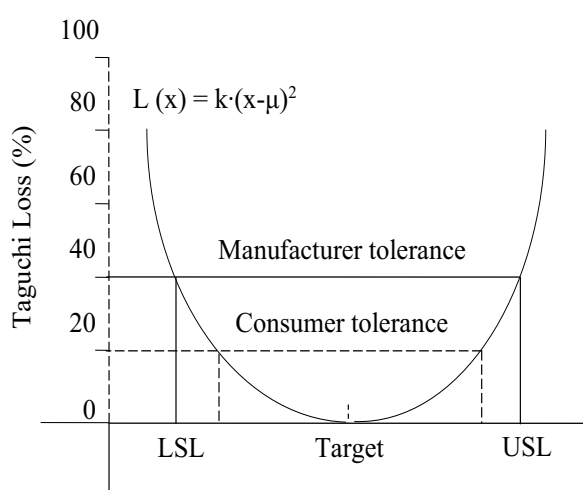


Figure 1. The two-sided equal specification Taguchi loss function (adopted from [46]).

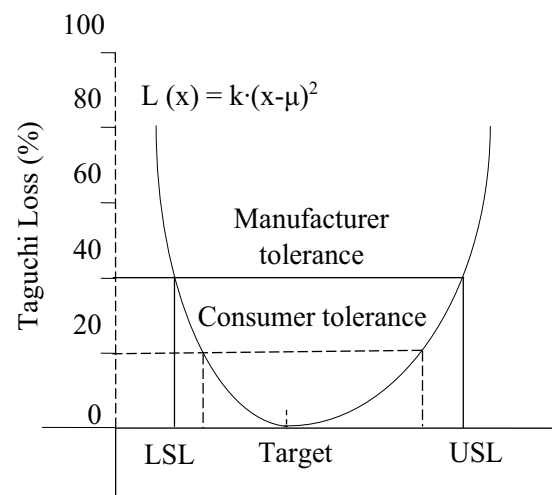


Figure 2. The two-sided with specification preference Taguchi loss function (adopted from [46]).

In two-sided functions, variation is allowed in both directions from the target value. In Figure 1, both lower and upper limits have equal distance from the target value. It means that characteristics measurements equally vary, towards lower and upper limits. On the other hand, Figure 2 shows that for some characteristics, less variation is allowed – in this case, towards the low specification limit (or it could be vice versa).

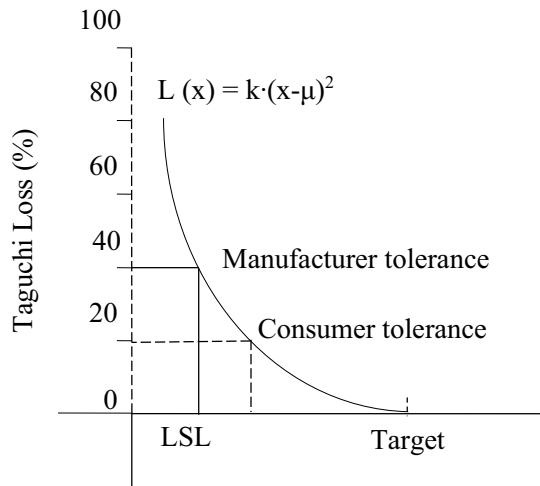


Figure 3. The ‘higher is better’ Taguchi loss function (adopted from [46]).

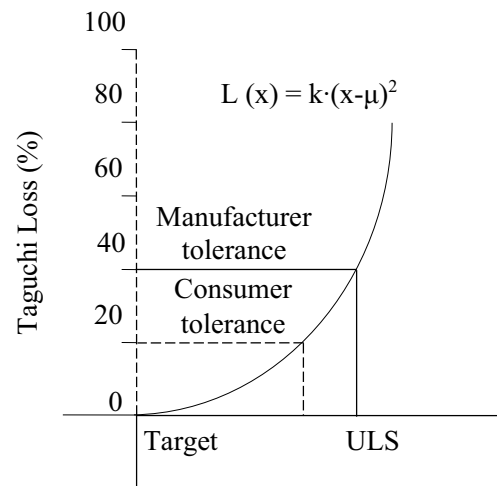


Figure 4. The ‘smaller is better’ Taguchi loss function (adopted from [46]).

A second TLF type is related to characteristics in which higher values are preferable (Figure 3). In that case, zero loss is at the target value and each deviation from target value towards the lower specification limit will result in loss. Finally, the third type of TLF is used for characteristics for which smaller values are desirable (Figure 4).

2.2. Literature review

When it comes to the food sector, the Taguchi approach in terms of loss function and orthogonal array (OA) has not been widely used. Up to now, the most common areas for Taguchi approach applications were: the managing and controlling the equipment, facilities, machines, electronic circuit technology, metal industry, computer science etc. According to previous literature about the Taguchi approach, its application in the food sector was barely in focus. In this paper, Table 3 gives an overview of the latest publications associated with food production, specific food related processes and food products. Application of Taguchi approach was much more common in studies of food process optimization than in designing food product quality.

Table 1. Compilation of papers in the food sector in which the Taguchi approach has been used

Implementation areas	Description of design	Result	Ref.
Food related process	Application of TLFs in process of filling bottles.	Process optimization and reducing costs.	[33]
Food product	Parameter design experiment was conducted in order to develop a caramel formulation in relation to the effect of the external noise factor – temperature.	Optimal caramel product formulation.	[34]

Food related process	Application of the Taguchi method for tea-beverage customers segmentation into 5 clusters.	Effective market segmentation.	[35]
Food related process	Parameter design was applied using TLF based on four attributes - quality, on-time delivery, price and service.	Development of method for supplier evaluation and selection.	[36]
Food production	Taguchi orthogonal array (OA) method was used. Six factors in biscuit production line.	Investigation of factors that mostly affecting food processing system.	[37]
Food production	Taguchi method was used to optimize the manufacturing process of bread production.	Optimal setting of parameter.	[38]
Food production	Taguchi OA method was used to optimize the process factors for developing ready to eat peanut chutney.	Optimized treatment.	[39]
Food related process	OA was applied to design experiments.	Optimal parameter design for increasing the yield of caffeine removal.	[40]
Food related process	Taguchi technique was used to optimize postharvest handling process.	Optimum conditions for handling and storing eggplant.	[41]
Food product	OA was applied to optimize the baking parameters (product formulation).	The optimal formula for producing a djulis sourdough bread.	[42]
Food related process	Taguchi method was used to optimize microwave frying process and its parameters.	The optimum condition for frying.	[43]
Food related process	TLF were used for evaluating quality loss.	Development of supplier evaluation and selection process.	[44]
Food product	OA was applied to determine the optimal production process and composition of candied carrot.	Best combination of parameters.	[45]

As can be seen in Table 1, the Taguchi approach has been used in various food sectors, but no application to fresh meat quality has been reported.

3. Taguchi approach in measuring marbling

Potential application of the Taguchi approach in evaluating fresh meat quality losses associated with marbling is presented in the flowchart (Figure 5). The details of these steps are briefly described in the following sections.

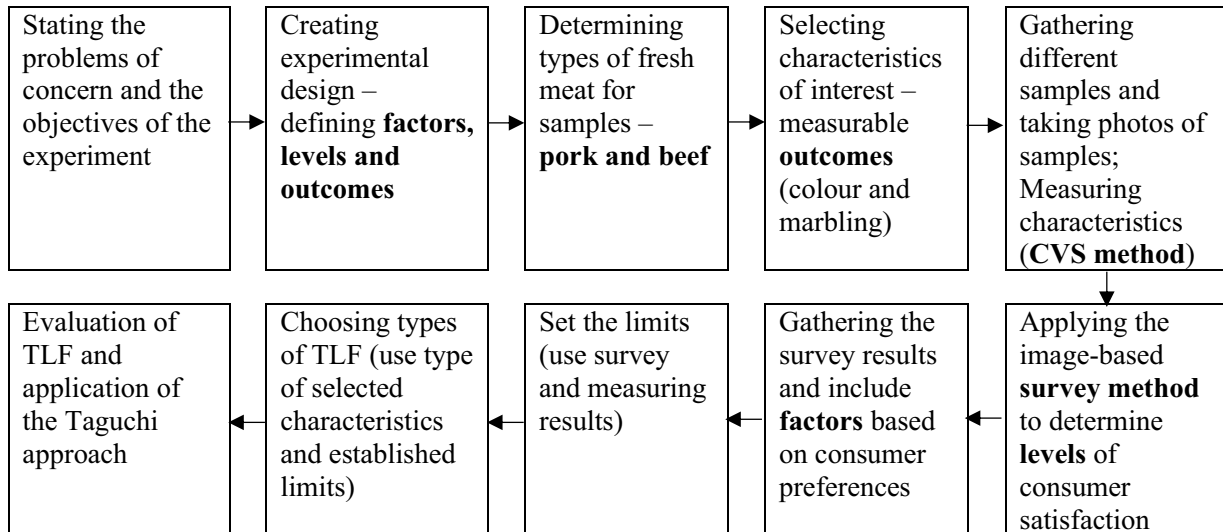


Figure 5. Flowchart of the potential application of the Taguchi method in evaluating fresh meat quality losses.

3.1. Stating the problems of concern and the objectives of the experiment

The experimental design of Taguchi-based approach is conducted by stating the problems of concern that in our case refer to inadequate marbling as quality loss occurrence in meat production and tendency for consumers' needs to be better understood. Hence, the main objective of this paper is to identify and calculate losses in fresh meat production that are related to consumers' dissatisfaction. Using TLF it is possible to evaluate every loss due to product manufactured with quality characteristics that deviate from the target value.

3.2. Creating experimental design

The experimental design consists of planning the experiment (determining types of fresh meat for samples and selecting the quality characteristics and measurement systems) and performing the experiment that considered steps from gathering different samples to the end of the flowchart (Figure 5). Gathering different samples, in this flowchart, means choosing samples with different levels of marbling. Thus, after samples are photographed, the image-based survey would show different levels of marbling of pork and beef meat to consumers. In this part of the experiment, consumers should be asked to select their preferred chop from presented images, considering marbling. Additionally, the consumers would be asked to select their maximum and minimum acceptable levels of marbling. Measuring quality characteristics would start by using CVS [22], after the pictures of samples are captured.

3.3. Potential application of Taguchi loss function

Based on consumers' responses to the survey and previous measurements, limits for marbling could be set. After quality characteristic limits are set, types of TLFs could be chosen. Defined inputs for application of TLFs are marbling measurements. Methodology for evaluation of Taguchi losses would be modified according to the work of Kethley et al. [46]. Such methodology suggested conversion of the raw performance measurements into the common Taguchi unit of measure, the percentage of loss for particular characteristic. Figure 6 shows a generic TFL.

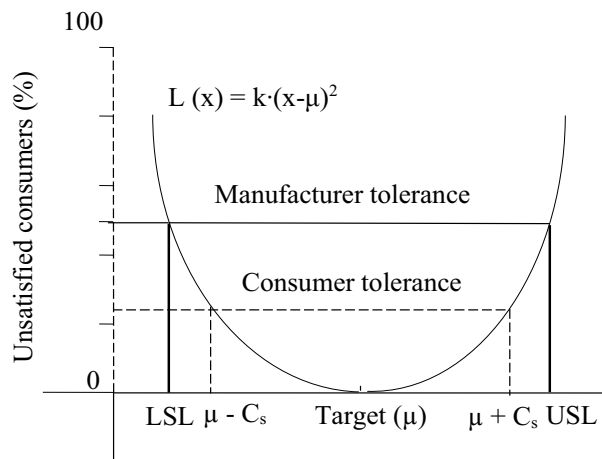


Figure 6. Generic TFL.
LSL – lower specification limit (determined as minimal marbling share); USL – upper specification limit (determined as maximal marbling share); C_s – level of customer satisfaction.

Let x be the level of marbling of the fresh meat and μ the consumers' preferable level of marbling. $L(x)$ denotes the loss due to the difference between x and μ . When $x < \mu$, the level of marbling is undesirably smaller than the target value, and when $x > \mu$, the level of marbling is undesirably bigger than the target value. If the process goes in this direction of deviation, towards functional ($\mu - C_s$ and/or $\mu + C_s$) limits, we consider it as consumers' tolerance (at 50% of unsatisfied consumers). Any possible value of x (characteristic measurement) within scope from the target to the LSL or from the target to the USL represents consumers' dissatisfaction.

4. Conclusion

As the Taguchi approach is designed to identify quality characteristic levels that most closely match the consumers' preferences and at the same time provide relation to quality losses, its validation should be under consideration in future research. Therefore, a combination of instrumental techniques, consumers' preferences and Taguchi loss function analysis can provide realistic data to develop a product with optimal levels and limits of key quality characteristics. This study can be used as the basis for designing applications of Taguchi loss function in other meat production areas, such as production of fermented sausages, dry meat, hamburgers, cooked hams and other meat products.

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