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Fuzzy concepts applied to food product quality control: A review

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Abstract

Fuzzy logic is now a wide field of study and different tools have been developed over the last 10 years. Its implementation in food quality control for the food industry has been highlighted by several authors that have focused on different applications designed specifically for this task. This is especially true in the case of taking into account the reasoning process, expressed in linguistic terms, of operators and experts. Nevertheless, applications are still limited and few reviews on this topic are available. Consequently, the aim of this paper is to provide an overview of the application of fuzzy concepts to the control of the product quality in the food industry over the past 10 years. Future interesting developments and trends in this area are also emphasized.

Keywords: Food processes; Fuzzy logic; Control; Quality; Review

1. Introduction

In the food industry, end-products must achieve a compromise between several properties, including sensory, sanitary and technological properties. Among the latter, sensory and sanitary properties are essential because they influence consumer choice and preference. Nevertheless, managing these properties right from the fabrication stage with the aim of controlling them is no easy task for several reasons:

- The food industry works with many parameters that must be taken into account in parallel. A single sensory property like colour or texture can be linked individually to several dimensions registered by the human brain.
- The food industry works with non-uniform, variable raw materials that, when processed, should lead to a product that satisfies a fixed standard.
- The phenomena involved in the processing are highly non-linear and variables are coupled.
- The food industry operates with very diverse processes and products and has requirements in terms of the portability and adaptability of the systems developed.
- Little data are available in traditional manufacturing plants that produce, for example, sausage or cheese and this situation is general throughout the food industry. Furthermore, even when databases do exist, it is not always possible to use them for controlling food product quality.

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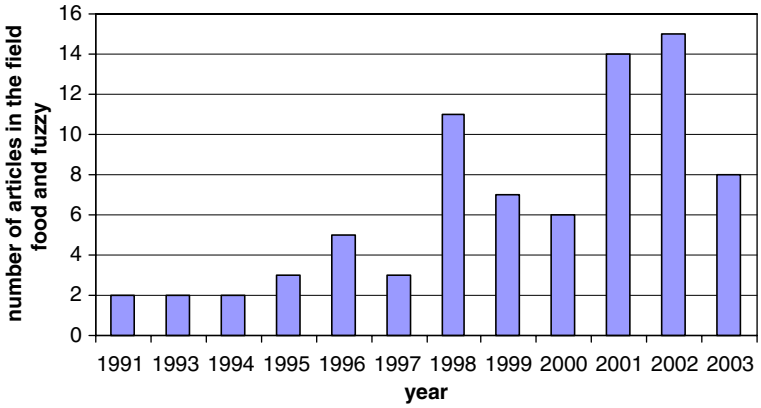

Fig. 1. Number of articles published in the field crossing the fuzzy logic and the control of the food processes.

In this context, despite the fact that the design of standards and reliable procedures for controlling the quality of products is a major objective for the food industry, automation is limited:

(i) Few sensors are available to carry out such measurements. Although new sensors have been developed such as artificial noses, the road is difficult and long and inaccessible for SMEs.
(ii) For several processes, it is difficult to established models sufficiently representative of the phenomenon involved, even for control purposes.
(iii) Classical automated approaches are limited for the reasons mentioned below.

At present many production processes rely to a great extent on the skill and experience of the operator, something that no system will be capable of replacing in the foreseeable future. Consequently, in practice, operators often play an important role and cooperate with automation so as to (1) make on-line evaluations of the sensory properties of the product and/or (2) adjust the on-line process. Moreover, experienced operators make macroscopic interpretations of the physicochemical phenomena that appear during processing, which can act in synergy with classical engineering knowledge on the process.

Integrating operator and expert skill in a control framework is a relevant direction, especially for traditional processes. Nevertheless, it leads to designing mathematical tools that have to integrate (i) reasoning based on the use of linguistic symbols such as "over-coated", "good colour", etc., expressed not on a numerical scale but on a discontinuous graduated scale and referring to an evaluation of a deviation in comparison to a set point; (ii) an uncertainty on these symbols that is translated after fusion in a specific action; and (iii) an action that is the result of an implicit or explicit interpolation between two specific state recorded by the operator over time.

Fuzzy sets and possibility theories were introduced by Zadeh in 1965 [92] as an extension of the set theory by the replacement of the characteristic function of a set by a membership function whose values range from 0 to 1. It is now a wide field of study that has seen the development of different tools over the last 10 years. Applied to the control of product quality in the food industry, it has been considered as pertinent by several authors for different applications and especially for taking into account the reasoning process, expressed in linguistic terms, of operators and experts [18,24,48,66,77,94]. Nevertheless, applications are still limited and few reviews on this topic are available.

In this framework, the aim of this paper is to provide an overview of the application of fuzzy concepts for controlling product quality in the food industry over the last 10 years.

The first papers on this topic appeared 15 years ago although the volume of literature really began to increase from 1996 (Fig. 1). All in all, 78 applications have been dedicated to this topic over the last 12 years.

This topic involves different subjects: (1) representation of the descriptive sensory evaluation performed by a quality team, an operator, or a consumer; (2) indirect measurement of the properties of a food product; (3) diagnosis, supervision, and control of food quality. The proportion of papers dedicated to each of these research fields is illustrated in Fig. 2, which shows more than 80% of papers being dedicated to fields (2) and (3), thus they are well represented in comparison