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Abstract. *Food chain analysis is a highly complex procedure since it relies on numerous criteria of various types: environmental, economical, functional, sanitary, etc. Quality objectives imply different stakeholders, technicians, managers, professional organizations, end-users, public collectivities, etc. Since the goals of the implied stakeholders may be divergent, decision-making raises arbitration issues. Arbitration can be done through a compromise – a solution that satisfies, at least partially, all the actors – or favor some of the actors, depending on the decision-maker's priorities.*

Several questions are open to support arbitration in food chains: what kind of representation and reasoning model is suitable to allow for contradictory viewpoints ? How can stakeholders' divergent priorities be taken into account ? How can the conflicts be solved to achieve a tradeoff within a decision-support system ?

This paper proposes an artificial intelligence-based approach to formalize available knowledge as elements for decision-making. It develops an argumentation-based approach to support decision in food chains and presents an analysis of a case study concerning risks/benefits within the wheat to bread chain. It concerns the controversy about the possible change in the ash content of the flour used for commonly consumed French bread, and implies several stakeholders of the chain.

Keywords. Decision-making, quality construction in food chains, sustainability, benefits and risks analysis, knowledge representation, reasoning, argumentation, decision-support.

Introduction

Food quality assessment relies on criteria classically grouped into four main types: nutritional, sensorial, service or practicity and sanitary quality. These can be supplemented by other emerging concerns such as environmental quality, economic quality, etc. However, all of these aspects of quality and their various components are not always compatible and their simultaneous improvement is a problem that has no simple solution. Moreover the importance attached to the different involved criteria varies among several stakeholders.

A tradeoff between nutritional, organoleptic and sanitary quality has been built in an empirical way within agri-food chains, with progressive control of transformation processes. With the emergence of new concerns and requests, consumers are becoming more receptive to these new problems and new tools are needed to meet emerging needs by adapting, innovating, optimizing decision schemes within agri-food chains.

This paper proposes an artificial intelligence-based approach to allow the formalization of available knowledge as elements for decision-making, based on an argumentative decision system. Very few studies deal with the advantages of argumentative methods as explanation elements for decision support (Amgoud and Prade, 2009), which is the question considered here. The paper presents an analysis of a case study concerning risk/benefit evaluation within the wheat to bread chain, according to recommendations for more whole-grain products given by the PNNS public health policy in France. It gives a brief overview of the results obtained in (Bourguet, 2010) through a simplified version of the model and an extract from the data.

Materials and Methods

Information sources

Several kinds of information sources were used in this study. They include, from the most to the least formal ones:

1. scientific peer-reviewed articles;
2. technical reports or information published on websites;
3. scientific conferences and research project meetings;
4. expert knowledge obtained through interviews.

For the considered case study concerning the position of the bread chain regarding the PNNS recommendations, we used the following sources. The scientific peer-reviewed articles we analyzed include Bourre et al. (2008), Slavin & Green (2007), Dubuisson-Quellier (2006), Ginon et al. (2009).

We also analyzed several scientific conference proceedings, and examined numerous technical reports available on official websites concerning the PNNS public health policy (PNNS statutory documents, 2005; PNNS website, 2005), the Healthgrain European project (Dean et al., 2007; Healthgrain, 2009), French projects and symposiums concerning sanitary, nutritional, sensorial and technological qualities of breads (Dinabio, 2008; Cadinno, 2008; Aquanup, 2009; FCN, 2009).

Finally, several interviews were conducted to collect expert knowledge from domain specialists covering various aspects of the bread chain, from health and organoleptic concerns to millers' and bakers' technological or economic concerns.

Argumentation models

Argumentation is a reasoning model based on the construction and evaluation of interacting arguments. Most of the existing models are grounded on the abstract argumentation framework proposed in Dung (1995). In this framework, an argumentation system is defined by a set of arguments *A*, and an attack relation between arguments *R*. Sets of arguments that « make sense » together are then computed, called *extensions*.

Thereafter, ensuing studies enriched Dung's model with complementary features, such as the consideration of preferences among arguments, expressing that some arguments may be stronger than others, or the consideration of contexts (see Bourguet et al., 2010 for a comparison of models).

Classically, the argumentation process follows three main steps : 1) constructing arguments and counter-arguments, 2) evaluating the acceptability of the different arguments, and 3) concluding.

Results

Argument Inventory and Formalization

In this case study, policy decision consists of global recommendations aimed at changing the type of flour used in the common French baguette bread sold in bakeries and retailed in institutional or school catering. The PNNS recommends to develop the consumption of breads made with more whole wheat flour, such as 80-type flour, instead of the 65-type currently used (i.e., containing 0.80 g of minerals per 100 g of flour on a dry basis, instead of 0.65 g per 100 g). The recommendations are mainly supported by nutritional arguments, related to increasing fibers, and buttressed by economic arguments related to increasing yield of raw material extraction (wheat).

Two alternatives can be pointed out : change common bread to 80-type flour (denoted by T80) or keep 65-type flour (denoted by T65). Table 1 lists the PNNS arguments, which take into account different concerns (Nutrition, Technology, Economy), pursue several goals (%Fibers, %Micronutrients, Process Skills, Costs) and is in favor of the T80 option.

Table 1. Part of PNNS argumentation.

	Stakeh.	Reason	Action	Concern(s)	Goal(s)
1	PNNS	"Using 80-type flour (T80) instead of 65-type flour (T65) for global breadmaking is relevant."	$\curvearrowright$ T80	Nutrition	$\nearrow$ Fibers $\nearrow$ Micronutrients (μnut.)
2	PNNS	"T80 reduces costs due to an increased milling yield."	$\curvearrowright$ T80	Technology Economy	$\searrow$ Process Skills $\searrow$ Costs
3	PNNS	"High-fiber diet reduces the public health costs."	$\curvearrowright$ T80	Economy	$\searrow$ Costs
4	PNNS	"Raising the daily T65 consumption involves increasing salt intake in the diet."	$\curvearrowright$ T80	Nutrition	$\searrow$ Salt

However, these arguments are hampered by other viewpoints and strong reserves on behalf of the concerned wheat processing stakeholders. For instance, baker and miller professionals are apprehensive about possible impacts on their core activities. The French milling profession is pushing for a reconsideration of the PNNS recommendations. A scientific report investigating nutritional impacts of 80-type flour was used. In Table 2, we list arguments from millers' profession, which take into account new concerns and support the conservative option (Action = T65) or a reconsideration of the recommendation (D. for “debranning”, O. for “organic”).

Table 2. Part of millers’ argumentation.

	Stakeh.	Reason	Action	Concern(s)	Goal(s)
1	Millers	“Raising the flour extraction rate causes an increase in flour contaminants.”	↻ T65	Sanitary	↘ Mycotoxins ↘ Pesticide Residues
2	Millers	“Wheat pretreatments (such as debranning) could decrease mycotoxins.”	↷ T80 & D.	Sanitary Technology	↘ Mycotoxins ↗ Process Skills
3	Millers	“Wheat pretreatments increase process costs.”	↻ T65	Economy	↘ Costs
4	Millers	“Making organic bread allows to avoid pesticide residues.”	↷ T80 & O.	Sanitary Economy	↘ Pesticides Residues ↗ Segmented Supply
5	Millers	“Raising flour extraction rate causes a rise in phytic acid.”	↻ T65	Nutrition	↘ Phytic Acid

Other arguments, in particular from miller and baker professionals, are not presented here for space reasons.

Argumentation-based decision model

We propose an extended decision framework, which takes into account a set of arguments *A*, a set of concerns *C*, a set of actions *D* (for « Decisions »), a set of (ordered) goals *G*, defined as follows.

Definition 1*:* An extended argumentation-based decision framework is a tuple $(A,C,D,G,\geq,\alpha,\gamma)$ where:

- $C = \{c_1, \ldots, c_n\}$ is a set of concerns;
- *A* is a set of arguments, divided into several subsets $A_1, \ldots, A_n$ of arguments that are expressed in the concerns $c_1, \ldots, c_n$ respectively;
- *D* is a set of mutually exclusive actions;
- *G* is a set of goals;
- $\geq = \{\geq_1, \ldots, \geq_n\}$ is a set of (preorder) relations on G. Each $\geq_i$ defines a preference ordering of the goals G, that applies for the concern c_i;
- α is a function: A → D that associates each argument with an action;
- γ is a function: A → G that associates each argument with a goal.

Based on this definition, the attack relation R is then computed in the following way: for a given concern, an argument *a* attacks an argument *b* if and only if their actions are mutually exclusive and the goal of *b* is not preferred to the goal of *a*. This is formalized by Definition 2.

Definition 2*:* Given an extended argumentation-based decision framework $(A,C,D,G,\geq,\alpha,\gamma)$,

$R = \{R_1, \ldots, R_n\}$ is a set of attack relations, respectively defined on $A_1, \ldots, A_n$ such that:

$$\forall(a,b) \in A_i^2, [(a,b) \in R_i] \Leftrightarrow [\alpha(a) \neq \alpha(b) \text{ and } (\gamma(b),\gamma(a)) \notin >_i].$$

For each concern, arguments and attacks are now defined and can be evaluated as in a classical Dung's system.

Case study output: an illustration

To use the proposed model, the following steps are successively performed:

1. Obtain a representation of all arguments, with their associated stakeholders, concerns, goals and actions.
2. Define preference relations between goals for each concern, according to their prioritizations.
3. Deduce the attack relation between arguments.
4. Compute the decisional resolution which leads to recommending one or several actions.

In this example, we propose to deal with sanitary concerns. Different preferences and the corresponding output recommendations are summarized in Table 3. The two recommendations "debranning wheat flour" (T80 & D.) and "organic bread" (T80 & O.) can be aggregated into a single recommendation "debranning and organic bread" (T80 & D.O.) since both actions are compatible. In the economic concern, this output can be counterbalanced. For instance, none of these actions is recommended when reducing costs and increasing benefits are preferred.

Table 3. Different preference scenarii and associated outputs in the sanitary concern.

Preferences	Recommended Action(s)
$\searrow$ Mycotoxins $\geq$ $\searrow$ Pesticide Residues	↻ T65, ↷ T80 & D.
$\searrow$ Pesticide Residues $\geq$ $\searrow$ Mycotoxins	↷ T80 & O.
$\searrow$ Mycotoxins $\approx$ $\searrow$ Pesticide Residues	↻ T65, ↷ T80 & D., ↷ T80 & O.

Conclusions

As with any policy action, decision makers rely on arguments from relevant concerns (health, economy, service, etc.) to recommend a decision with positive impacts. Thereby in the PNNS public policy, preferential concerns are health and nutrition, nevertheless secondary concerns such as processing, economy or hedonism also appear in several assessments. The approach described in this paper consists first in formalizing real world arguments and secondly in proposing an extended argumentation-based decision framework. The case study represents an original approach in the A.I. field and an introspective approach in the agrifood chain field.

Future trends in decision support tools involving argumentation methods should be a relevant way to help the stakeholders eliciting and formalizing arguments, which would make them more involved in the decision process and would facilitate interactions between all the stakeholders. Such a decision support system can also be of interest to target a food product for a given (and not a global) segment of consumers. More generally, arbitration-driven argumentation is a promising approach to help humans make well balanced decisions, considering for instance the three pillars of the sustainability concept (social, environmental and economic).

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