An Application of a Fuzzy-based Optimisation Model for Selecting Food Products based on Cost and Nutrition

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For consumers with limited financial resources, both the total healthiness of the food product and the affordability are equally critical determinants in choosing basic food products. The application of fuzzy based methods enables a systematic selection of food products based on cost and nutrition factors considering subjective judgements and imprecise nature of decision inputs. In this study, each type of nutrient and the price of food item are expressed as fuzzy sets. The total nutritional value based on the harmonic mean of nutrients in the food product indicates its degree of healthiness. The contextual knowledge and domain expertise in health and diet are integrated to generate a set of fuzzy rules that identifies best purchase decisions. By taking wholemeal bread brands in supermarkets as an example, the empirical application of the proposed method is illustrated. This method can accommodate more decision variables and has the flexibility to accommodate different socio-economic conditions and consumer requirements by changing input variables and fuzzy rules.

Purchase decisions about food items have become complex due to the enormous variety of available products of any particular food item in the market. These purchase decisions are influenced by a multitude of factors including, price, nutrition knowledge and level of literacy of the purchaser, freshness of food, food beliefs, in-store stimuli and packaging. For some consumer groups and public nutrition programs such as those in school canteens, aged care facilities or boarding houses, nutrition and price are especially significant factors in the food selection decision because funds and/or subsidies are often quite restricted.

The application of fuzzy based methods enables a systematic selection of food products based on cost and nutrition factors considering subjective judgements and imprecise nature of decision inputs. The previous use of fuzzy logic for decision-making in nutrition, demonstrated that there is no single optimal intake value but a range of intake values for a nutrient (Wirsam et al. 1997). This paper develops a method that integrates both cost and nutrient optimisation for decision-making in food selection allowing the flexibility to match the different economic and social conditions of targeted consumer groups.

Fuzzy-based Method and Its Application

The raw data of input variables of price and nutrients are collected as deterministic values known as crisp values which are then converted into fuzzy sets. Crisp values of individual nutrients are fuzzified and then assessed together to determine the level of healthfulness of the food item by calculating the Prerow value (Wirsam and Uthus 1996). Depending on the input variable values, applicable fuzzy rules are selected and fired to generate the output predicates. The fuzzy value of the output variable is generated using the Mamdani operator. In the defuzzification process, the output fuzzy values are converted back into crisp values by using the Centre of Area method.

We demonstrate the proposed methodology by evaluating wholemeal bread brands. Wholemeal bread brands with fortified nutrients are excluded to consider only the regularly present common nutrients of energy, carbohydrate, dietary fibre, protein, sodium and fat. Data were collected in three major supermarkets in two urban Sydney suburbs, on the 17th of August 2012. Regular prices of products were recorded even though some products were on promotion on the data collection date. The German nutrition recommendations (DGE 1992) are used for cconstruction of membership functions of each nutrient based on the similarity between Australia and Germany as industrialised economies. Table 1shows the nutrient values and the price of average serve size of each bread type.

Table 1: Nutrient values and the price of 136g of each bread type

Wholemeal bread Sample	A	C	D	F	G	H
Energy (g)	1278.4	1400.8	1391.28	1332.8	1346.4	1347.76
Protein(g)	13.056	13.736	12.92	11.696	12.24	13.056
Fat, total (g)	2.176	4.76	2.856	2.448	2.584	4.896
Carbohydrate (g)	54.4	54.4	58.888	58.616	57.12	51.816
Dietary fibre (g)	3.264	8.84	9.112	5.848	8.704	8.024
Sodium (mg)	625.6	544	544	523.6	544	529.04
price per two average serves ($)	0.87	0.69	0.58	0.31	0.31	0.31

The membership function of the healthiness, H given by the Prerow value is in the range of 0-1. The predicate functions as shown in Figure 1, were informed by the fuzzy membership functions for linguistic variables of nutrients developed by Wirsam and Uthus (1996).

μh(H) = {CL,CR,BS,S,OP} where CL=Clinical, CR=Critical, BS=Barely Sufficient, S=Sufficient, OP=Optimal}

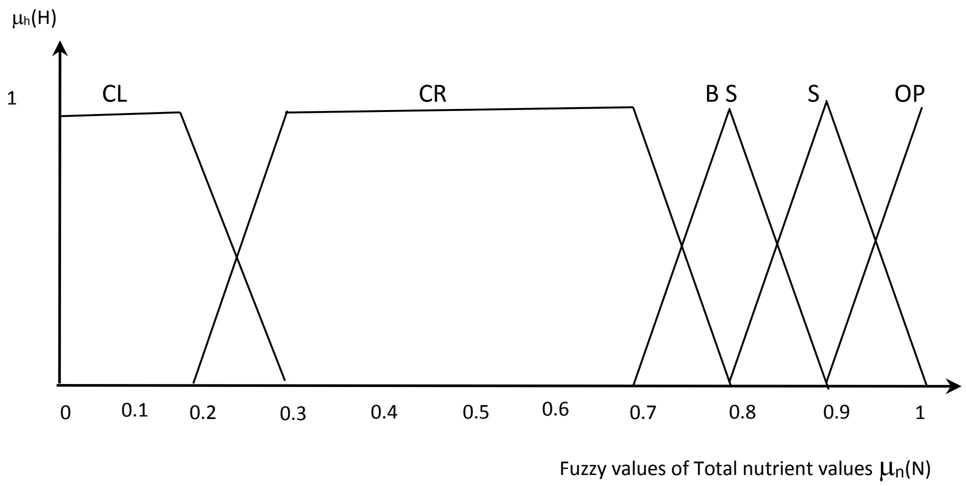

Figure 1: Membership values of the level of healthiness of bread

The price of a wholemeal bread loaf of 700g varies between $1.50 and $6.00 in supermarkets. Thus the price of two serves varies between 29 cents and $1.17. The price range for the analysis is considered to be between $0 and $1.50. The membership function, $\mu_p(P)$ of the input variable of price, P is shown in Figure 2.

$\mu_p(P)$={VC,C,A,E,VE} where VC=Very Cheap, C=Cheap, A=Acceptable, E=Expensive, VE=Very Expensive

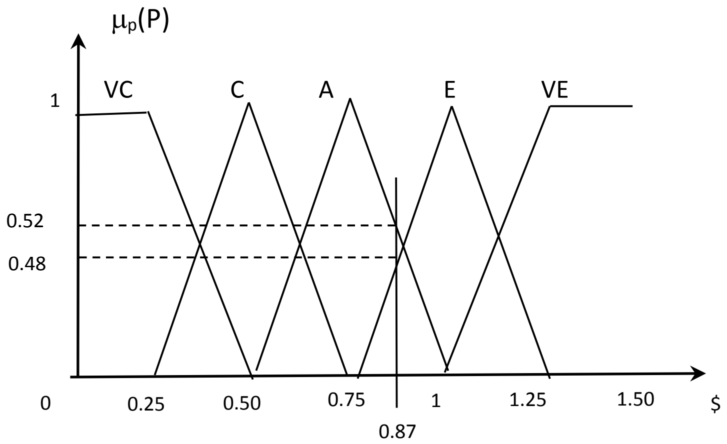

Figure 2: Membership function of price of 136g of wholemeal bread, P

The membership function of the output variable of the purchase decision, $\mu_d(D)$ is shown in figure 3.

$\mu_d(D)$={NC, NR, JR, R, HR, B} where NC=Not to be considered, NR=Not Recommended, JR=Just Recommended, R=Recommended, HR=Highly Recommended, B= Must Buy

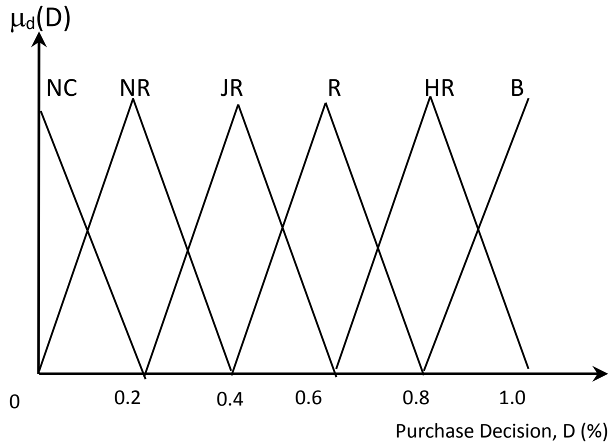

Figure 3: Membership values of the purchase decision, D

The fuzzy rule set that consists of if-then statements developed by knowledge experts in health and nutrition with a good contextual understanding of the socio-economic conditions of the target consumer groups is given in table 2. The fuzzy rules are for the two input conditions of healthiness and price of the type of wholemeal bread and the output of the purchase decision.

Table 2: Fuzzy rule table

Decision, (D)	Healthiness, (H)				
Price, (P)	Clinical	Critical	Barely Sufficient	Sufficient	Optimal
Very Cheap	NR	NR	JR	HR	B
Cheap	NR	NR	JR	HR	B
Acceptable	NC	NR	JR	R	HR
Expensive	NC	NC	NR	JR	R
Very Expensive	NC	NC	NC	JR	JR

The raw value of each nutrient of each sample was converted into daily intake values based on the average adult diet of 8700KJ as used in all sample items. These crisp and fuzzy values of nutrients of sample A are tabulated in table 3.

Table 3: Main nutrients and fuzzy values of the sample A

Nutrient	Crisp value	fuzzy value
Energy (calories)	7896	0.9
Protein (g)	47.43	0.9
Fat calories in % of energy intake)	21.38%	1
Carbohydrate calories in % of energy intake	59.65%	0.97
Dietary fibre (g)	11.2	0.74
Sodium (mg)	2576	0.975

The value of price, P which is $0.87 cuts the A predicate at 0.52 and E predicate at 0.48 in the fuzzy set shown in Figure 2. The total level of nutrition of the type A bread is 0.905. The membership value for input variable, total healthiness, cuts the S predicate at 1 in the fuzzy set which is shown in Figure 1. Based on these values two rules can be activated as shown in table 4 from the fuzzy rules sets in table 2. Fuzzy values are also generated by using the Mamdani Operator for implication as shown in table 3.

Table 4: Applicable fuzzy rules

Rule #	'If' clause	'then' clause	Composition Results
1	If Healthiness is Sufficient and Price is Acceptable	Purchase decision is Recommended	1^0.52= 0.52
2	If Healthiness is Sufficient and Price is Expensive	Purchase decision is Just Recommended	1^0.48= 0.48

These output fuzzy values and the predicates are aggregated to generate the final fuzzy set as shown in Figure 4.

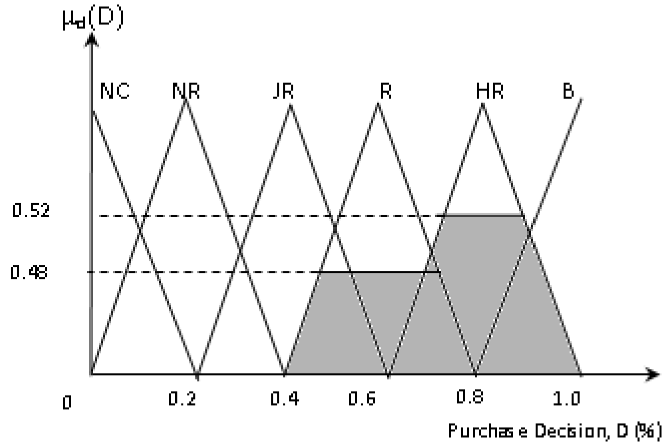

Figure 4: Aggregated fuzzy values of the output variable

The output fuzzy values are converted into crisp values by using the Centre of Area method. The purchase decision for sample A is 46.10%. Similarly, the output values for all brands in the sample are calculated and given in table 5. With the highest output value, sample D is the optimum purchase because it provides the maximum healthiness at the lowest cost.

Table 5: Input and output values for all sample wholemeal bread types

Wholemeal bread type	A	B	C	D	E	F
Prerow value	0.90	0.93	0.92	0.96	0.95	0.93
price per two average serves ($)	0.87	0.69	0.58	0.31	0.31	0.31
Purchase Decision	46.10%	72.51%	75.77%	86.23%	84.43%	83.45%

Implications

The practical implications of this model are most specifically important for consumer groups who consider the identification of foods with optimum cost and healthiness is crucial. Implementing a systematic method as proposed in this paper enables integrating contextual preferences with the diet and health requirements in a positive manner through open discussions especially when this method is extended for cost and nutrition optimised menu planning. This method can be further developed into a software application for ease of adoption and to allow users to dynamically check the best foods with price changes or new products coming to the market. The consumer groups need the flexibility of adapting the fuzzy rule tables to fit the contextual conditions with expert advice.

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