Tripartite Flavour Model: Food Phenotype, Sensory and Interpretative Matrices

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Abstract. Among all sensory sciences, flavour remains a wicked problem while sight, sound, and touch have all been digitized. While the biological basis for food consumption is primarily to nourish bodily functions, it fulfills a greater second function of sensory pleasure. Flavor, and the pleasure it engenders, is the primary driver of food choice. Moving toward a semantic web of food that enables personalization of food and flavor experiences requires an interoperable ontological model of flavor. This paper proposes a framework of several ontologies to model a comprehensive view of flavor, by partitioning it into three interoperable matrices of interacting variables: objective characteristics of food, subjective sensory experience, and interpretive communication of that experience. Together these three matrices represent an initial ontological model for the flavor and sensory experience portion of the emerging semantic web of food.

1 Introduction

In 1973, two social scientists, Horst Rittel and Melvin Webber defined a class of problems they called “wicked problems”.[1] Wicked problems are messy, ill-defined, more complex than we fully grasp, and open to multiple interpretations based on one’s point of view. [2] Flavour among all sensory neurosciences remains a wicked problem. While many researchers have proposed methods for digital replication of specific tastes and aromas [3], to date there exist no semantic or ontological models for operating over food flavor and the sensory experience.

Selection of food for nourishment in animals is an evolutionary process, influenced by habitat and ecological conditions, whereby recognition of tastants and especially aromants are associated with (dis)pleasurable eating and post-prandial experiences, and highly influence future food choices. Learned consequences of ingested foods cross five sensory modalities of taste, aroma, texture/mouthfeel, colour and sound and this complex sensation is called Flavour. [4–6] Challenges for designing computational flavor systems are effectively highlighted by comparison to more developed computational neuroscience systems of vision and sound, where scientific research and technology successfully mapped physical properties of stimuli to their perceptual characteristics due to the continuous nature of their data. In vision, wavelength translates into a digital model color; in audition, frequency and wavelength translates into amplitude/pitch model. [3] This information digitisation provides unambiguous identification of colour and sound, without influence of perception or hedonic response. The separation of objective and subjective perspectives is our proposed solution to the wicked flavour problem, albeit the dimensionality of flavour is orders of magnitude greater than for sound or colour. Since the scope of this Flavour "model" is so vast, it requires a top-down modular approach. The Ontology of Nutrition Studies adopts the similar approach to curate heterogeneous nutrition data into ontologies and accordingly involve researchers from different nutrition-related fields (health sciences, agricultural sciences, food technology) where the same term has different semantics [7]. Another purpose of such a top-down approach is for better integration of ontologies by creating clear distinctions between high level domain ontologies and in depth ontologies.

2 Tripartite Flavour Model

The model in Figure 1 shows the three matrices. The first matrix enclosed by a curve dashed line represents the Food Phenotype Matrix, unbiased by individual response. The second matrix is enclosed in the human body boundary, represents the sensory capture and modulating factors in decoding the ingested food. The third layer still partly enclosed in the human boundary is the interpretation of the experience which is finally communicated.

2.1 Objective Properties

A food is composed of biological components and chemical components. Biological components includes bacteria and morphological features of the food, like germ, in a grain. Chemical components are all the molecules. Biological properties are the bioactivity roles. Chemical properties characterize the reactability. Physical properties include Rheological, Acoustic, Volumetric properties to name a few. Organoleptic properties felt as the sensation of touch, sight, smell, taste, sound, inflammation, and lacrimation is relevant to the consumption of food. The Food Phenotype Ontology in Fig 2 ,is designed to characterise a single-molecule food like table sugar, or a flour with several different molecule types as shown in Figure 3. Future development of the ontology will also consider modelling the structure of foods like lasagna. The top section of Figure 1 illustrates the transformation of a food by adding another food and/or the effect of time, process and environment.

2.2 Sensory Matrix

The sensory apparatus and neural processing is a highly-nuanced combination of psychological and physiological factors. The olfactory apparatus of 400 odorant receptors, [3] has variations across ancestry, age, and gender for over 70% of the explainable variance for some odors (guaiacol, diacetyl, and nonyl aldehyde) and less than half of the explainable variance for others[8]. The taste papillae in the tongue vary in density [9, 10] and these are some responses to tastes comparing high and low density groups; sucrose (196%), NaCl (135%) ,PROP (142%), Citric acid (118%) and quinine HCl (110%) [11]. Anosmia and hyposmia, the inability or decreased ability to smell, is estimated to afflict 3–20% of the population and is linked to old age,chronic sinonasal diseases or neurodegenerative diseases. [12] On the psychological front, stress caused changes in neuroendocrine balance (high cortisol and insulin) can lead to non-homeostatic eating patterns.

2.3 Interpretative Matrix

Folksonomies are the varied taxonomies across socio-cultural demographics. The origin is rooted in the communication theory of social constructionism; that human beings rationalize their experience by creating models of their social and cognitive processes and reify these models through language.[13] Research studies found that differences in expression that can be divided into three groups: sensory descriptors (hard, red, noisy); symbolic descriptors (interesting, expensive, modern); and affective descriptors (pleasant, beautiful)[14].

3 Conclusion

The semantic web of food critically depends on digital models of flavour for enabling predictive outcomes from food production, transformation, and ingredient combination processes relative to flavors, bioactive/nutritional properties, and ultimately health/behavioral outcomes. Modularization of the flavor model, as illustrated with bread example, considers the (future) role of measurements to support reasoning and decision making in any food processing sequence toward a desired food-phenotype outcome. The Food Phenotype model applied toward quality/grading standards of commodities like wheat, by virtue of characterizing the bread organoleptic properties, provides basis for price premium by consistent quality attributes. Finally, this framework while focussed on flavour and processing, enables connection to connection of flavor outcomes with production/transformation process energy usage, effluent production, and ultimately sustainability outcomes with specific flavor desires.

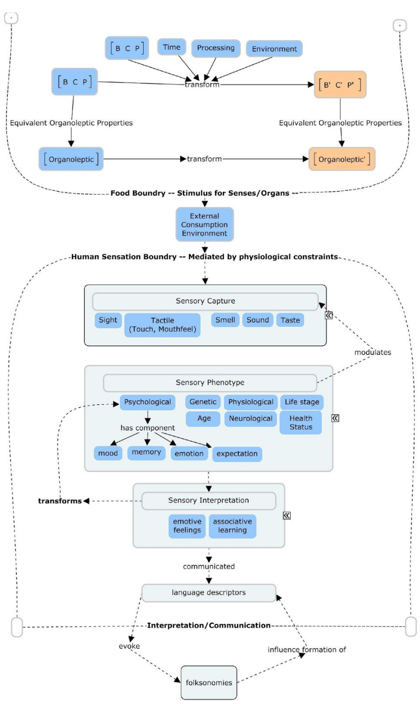

Fig. 1. Tripartite Flavour Model. Boundary lines separate three matrices.

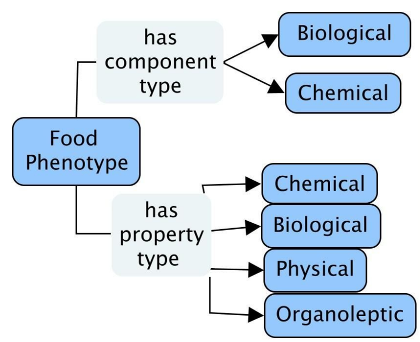

Fig. 2. Phenotype Ontology base classes

	Components		Properties		
Food/Ingr	Bio	Chem	B	C	P
Flour	Endosperm Germ Bran	Starch Gluten Lipids	*Bioactivity*	*Mol Stucture based properties*	Milled grain size
Water		Water		Hydrogen Bonding	
Yeast	RNA DNA	Proteins Sugars Lipids Minerals	*Bioactivity*	*Mol Stucture based properties*	
Dough	Air Bubbles Gluten Network Gelatinised Starch	Proteins Sugars Lipids Ethanol Yeast metabolites	*Bioactivity*	*Mol Stucture based properties*	*Dough Parameter Set*
Bread	Gluten Network Gelatinised Starch	Proteins Sugars Lipids Baked flavour compounds	*Bioactivity*	*Mol Stucture based properties*	*Bread Parameter Set*

Parameter Set	Variables
Dough/Bread	Elasticity
	Height
	Volume
	ph
	Total Titrable Acidity
	Dry matter
	Water activity

Ingr	Process	Matrix Parameters & Variables
Flour Water Yeast	Mix	BCP Process - force
Dough	Knead	BCP Process - force
Elastic Dough	Ferment	BCP Process - Time, Temp
Proofed Dough	Bake	BCP Process - Time, Temp, Humidity
Bread	Slice	Process - Force

Fig. 3. Bread as an example of the Objective layer. Fig 3a(top) gives details of the Phenotype Model. Note on terminology - *Parameter* is a set of variables; Fig 3b lists variables. (Not all *Parameters* are defined yet.) Fig 3c explains sequence of ingredient and process

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