Introducing Bioorganic Materials and Commodities Properties as "Unit Properties"

by Gianni Grasso

We introduce a non-conventional view of the different sets of properties of the bioorganic materials and commodities in the course of their life-cycle, i.e. technological, functional and environmental properties of foods, wood, paper, leather, textiles, petroleum etc. The described approach moves in the line of idea of the engineering "unit operations" and comes from the concepts of "unit structures" (reductionistic viewpoint) and "body-system" just as defined by the general Systems Theory (holistic viewpoint). Some practical examples show as the "unit properties" concept, put at the basis of the transdisciplinary proposed "technical theory", can be utilized in order to unify and rationalize any technical approach to these classes of commodities. In fact this idea allows to handle directly technical properties in terms of the scientific models associated to the various "unit structures", independently from the specific matrices of the considered materials or bodies, and so reverse any traditional descriptive and specifically dedicated approach.

A broad spectrum of industrial processes transforms bioorganic raw materials in final commodities such as wood, leather, pharmaceuti cals, cosmetics, foods, textiles or coal; i.e. handmades or formulates. Here we refer to both the structural *technological* and *functional* or commodity-performances characteristics [1] correlated, respectively, to the process parameters and consumer expectations [2]. Nevertheless also *environmental* properties could be considered, being our approach based on the systems general behaviour. Bioorganic materials constitute the biological bodies, that we can consider in a technological perspective as composite physical bodies structured on interconnected sub-systems [3], whose complexity can be deployed just recurring to the *"unit structures"* concept [4]. This latter allows us to consider such bodies and materials as independent from their specific origins and compositions.

This concept finds its morphological assumption on the fact that the Biological Sciences have already stated the teleonomic character of the organic structures as based on a logic biosynthesis system design. This latter is in turn founded on a mix of basic functional components (water, structural polymers, functional colloids, composite mechanical associations) and organization levels (molecular, supermolecular, corpuscular, tissued etc.) ubiquitarious among the biological species [5]. Therefore we can approach to a model description of the properties of the bioorganic materials as *"unit properties"* based on unit-structures, likewise independent from any specific material physical context. The same philosophy governs the Chemical Engineering sciences when introduce the industrial chemical processes as unit operations [6], concept that in the later 70s was applied to bioorganic commodities too [7, 8]. These materials are properly inclusions of several unit structures mutually dependent, nested the ones into the others such as in a chi-

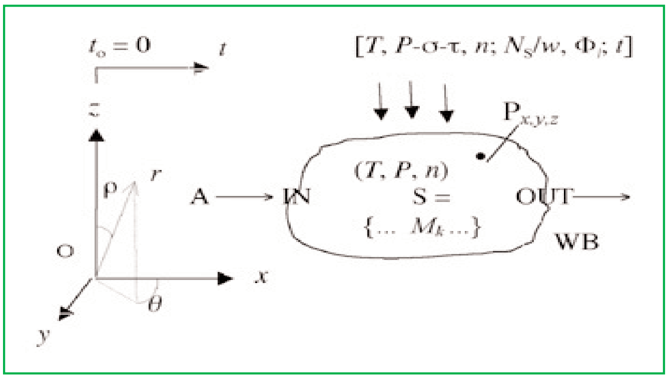

Figure 1 - Analogic model of the body-system defined in the space-time: O(x, y, z) = reference system specifying any inner space P_{xyz} position and r(θ, ρ) direction, $t_o = 0$ origin of any time t. A = surroundings, S = system, WB = wall-boundary, IN = stimulus, OUT = answer, $[T, P\text{-}\sigma\text{-}\tau, n; N_S/w, \Phi_I; t]_A$ = process parameters: (T, P, n) = thermodynamical state-variables tern, σ-τ = mechanical stesses, $[N_S/w]_A$ = microbial process parameters (fermentative inoculation or contamination, counts/weight units), Φ_I = field potential causing I_Φ force intensities

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EXAMPLE 1. Freezing temperature. Is a fundamental critical property of frozen foods, that has to be strictly controlled by both industrial and home freezing apparatus (e.g. the -18 °C limit value of the "freezing chain"), in order to assure the water solid-state and so block its action as solvent medium versus the biochemical metabolic reactions. The enucleated unit structure, involved in the phenomenon (solidification), is the liquid fraction of M; i.e. the chemical-physical system of M constituted by the physiological solution of body's cellular components (M_k = "solution" or homogeneous mixture of the various components: water, salts, sugars etc.). Further simplified model is a water-salt (NaCl) or water-sucrose binary solution, according to the prevalence of the second component, whose state is described, in term of chemical-physical system (thermodynamic), by the respective binary phase diagram (Figure 4a). In such systems (T, n_w, n_{salt}) or (T, n_w, $n_{sucrose}$) are the state variables (W = water), with eutectic temperatures of respectively -14 °C e -21 °C, very near to the -18 °C value meanly observed and forecasted by the "freezing chain".

nese box. Thereafter, while the approach to the processes is usually of the "serial connection" model (the whole process is the sequence of the single unit operations), that one to the materials is of the "parallel connection" model; i.e. the incoming signals-stimuli travel contemporaneously across all the material unit structures (Figure 1) and are roughly selectively absorbed only by someone or someone's unit structures.

The conceptual framework here presented starts from a series of previous papers where common aspects concerning the structures as well as the scientific, technical (processing) and functional (use) properties of the organic materials and products were formalized [9-15]. Based on the *systemic approach,* our pattern moves in the view of the 6th EC Framework Programme which clearly refers to the nanotechnologies, functional materials and to their "knowledge-based" holistic consideration [16]. This all seems to show the importance of including in a common interpretative-operative scheme, placed in the main field of the chemical-engineering sciences, even such categories of materials and their handmades. It is this systems approach that allows to consider the various properties and characteristics as coming from the "interactions" between the body-system and the different "surroundings" which materials interact with (Figure 1) in the course of their life-cycle.

EXAMPLE 2. Activity of a stabilizing agent (preservative). Preservation by chemicals is a necessary practice in all biorganic commodities such as foods, wood, textiles, leather etc. in order to prolong their life-cycle. The unit structure involved in the phenomenon (antagonism against decomposition, due to the inactivation of the microbial enzymes to which the molecule of preservative agent joins with hydrogen links) is the chemical system of M (M_k = "set or population of the components") in which is present the preservative chemical species AH dissolved in the physiological solution of body, e.g. ascorbic acid with $pK_a = 4.5$. The state of the active component involved in the phenomenon, is described, in term of chemical system (thermodynamic), by the respective distribution diagram of the concentrations AH/A$^-$ in water solution (Figure 4b), where (T, n_w, n_{H^+}) are the state variables. Is thus evident that the presence of the indissociated acid molecule AH, able to join at the enzyme E (interaction AH-E) and therefore to be the active species, it's conditioned by the acidity of the aqueous medium and particularly by values of $pH < pK_a$ (% of AH > 50).

The aim is to open to framing the materials and properties of the agro-industries and biotechnologies products in a wholly general unified treatment, based on general concepts that are valid in any context. We think a sort of Bioorganic Materials Science as propaedeutical knowledge to anyone more specialistic, concerning both bio- and agro-industrial technologies. Therefore we hope to have taken the first step toward the enlargement of the Materials Science concepts to such classes of commodities too. Further matter of interest is the opportunity to frame the action and properties of the nanostructures of technological application (e.g. colloidal microemulsions) in the complete 3D material context, chemical or physical, of the matrices where they operate (e.g. fibrous, porous, microtubular materials, including dispersions and intephase surfaces etc. strongly heterogeneous); that is on every scale-level, from subnano- to macro-. In the following pages, definitions and concepts of particular relevance, coming expressly from the various disciplines or expressly here introduced, are indicated in italics.

Epistemological aspects

We first suggest, as pragmatic, eclectic and simplifying resolution of the complexity of a biological material M, its *categorization* in the unit structures [4]. I.e. as a set S of all its coexisting M_k "structural categories", that time to time emerge in its behaviour as related to specific properties (e.g. molecules to chemical properties, microorganisms to biological deterioration properties, continuum to mechanical and transport properties and so on). In formal terms, $S \equiv \{...M_k...\}$ is a true syllabus of unit structures. Development of this concept starts from two remarks:

- In R&D any technological fact involving a given material is not generally isolated, but it has to be primarily understood *in the context of the whole material* system. In fact it usually involves a dominant unit structure strictly related to the property, the other structures being "suppressed" as details according to the *reductionistic* view, but that is nevertheless inserted among the others subsystems to which it is linked by interactions more or less strong (the indivisible whole of the systemic *holistic* view):

$S \cong M_k$ *reductionistic* hypothesis
$S \equiv M = \{...M_k...\}$ *holistic* hypothesis

Or, respectively, *ideal* and *real* behaviour, as pointed out in a following paragraph on system communication.

- In R&D any technologist has to operate in a context of materials behaviours and properties oriented at 360° (*totality* need), therefore besides a specialization in a given field he has also to possess a minimum of knowledge on the general models of the various phenomena involved. This horizontal knowledge has to have valence for all the agro-industrial technologies, as well as the technological transformations of the organic mineralized resources as coal or bitumen are (*flexibility* need).

The logic of the approach

Our logic incomes from toughing any sort of industrial commodity as an object that technologies can modify by means of some "actions" at the boundary (Figure 1), substantially of three types: thermal (T), mechanical (P-σ-τ) and concerning matter or energy transports, removing or transformation. Matter can be inanimate (chemical components p of moles quantities n_p) or animate (microorganisms s of number N_s), energy is exchanged as fluxes of field potentials Φ. From this viewpoint is already implicit the consideration of these products as physico-chemical *thermodynamical* systems, i.e. composed of phases and components, opened to exchanges with the surroundings. Nevertheless this description is reductive, because macroscopic and limited to only two categories of system elements (system = "grey box"). In fact it makes no specification about modifications of the other elements or sub-systems of the object (i.e. functional molecules exercising specific interactions, colloids, histological or particulate elements, microorgnanisms, continuous medium etc.), that otherwise in a project perspective have to be properly modified by the process because strictly connected to the desired functional properties of the final object. It seems therefore logic the general idea of *thinking the objects as systems* in strict meaning, i.e. in cybernetic sense, whose "black box" behaviour is described by the general laws of *statics* and *dynamics*.

Of these systems, or more exactly *systems of "sub-systems",* is further necessary a systematic characterization of their structure organization or morphology (system = "translucent box"). From this lecture-key, behaviour of these sub-systems needs to be organized in the frame of the general behaviour-laws of the systems (see next paragraphs). The startpoint of our idea is therefore the object as whole system, jointly considered outward its surroundings (as interactive body, *behaviour*) and inward its interior (as organized material, *structure*). Thus System Theory can really simplify any comparative approach to the technologies of different bioorganic materials and commodities, recognizing both structure and behaviour *isomorphisms* among the different sub-systems. I.e. analogies on systems behaviour laws and organization criteria of structure-levels (hierarchy, ubiquitarity, size-scale).

Analogic model of any technological object: the "body-system"

The assumption of our method finds therefore its natural foundation on the general Systems Theory [17, 18] and on the *body-system* or *material-system* concepts assumed as analogic models of any real body or material (Figure 1).

Such theory considers concepts, laws and principles valid for any system apart from its nature[1] (physical, biological, social, economical, linguistic etc.), and so valid also for the bodies or materials of technological interest but with the specific meanings of their context. In particular concepts of stimuli-answers or actions-reactions or causes-effects, i.e. input-output variables of the system (IN $\rightarrow S \rightarrow$ OUT) or input-accumulation (IN $\rightarrow S$[ACC]), and models or equations between the OUT/IN or ACC/IN variables. Those similarities constitute real isomorphisms stated by the Systems Theory among the different systems. Materials, being properly "systems of systems", as whole entities as single sub-systems are nevertheless "systems" and, of consequence, present common, primary isomorphic characteristics. The *external* system variables identify with "what enters" (independent IN values, produced or influenced by events *out* the system) and with "what goes out" or "what accumulates" (processed OUT/ACC values, dependent on events *inside* the system). According to the arrows orientation, IN represents the action of the environment (= process, experimenter, ecosystem) on the system; conversely OUT represents the (re)action of the system on the environment and ACC the effect of the action as is "metabolized" and retained in the *S* interior. Instead *inner* variables are correlated to IN/OUT amounts. The IN amounts, correlated to OUTs or ACCs, can change in the course of the time according to a "step shaped" function of instantaneous "jumps" from a given steady state to another one, or following a regular decaying trend, sinusoidal (pulsing) or completely random (stochastic).

Any system, being characterized by behaviour and structure, is quantified by their measurable *attributes*, or properties, such as its state-variables (thermal, mechanical and chemical of composition) and its macroscopic and microstructure parameters.

Symbolic models: laws of the system (behaviour and structure)

Correlation between system stimulus/answer variables:

OUT = κ_j IN^n or ACC = κ_j IN^n behaviour laws

EXAMPLE 3. Activity of an emulsifying agent (emulsion of oil in water or O/W). Emulsions cover a wide sector in all bioorganic commodities, such as mayonnaise, sauces, water-based varnishes, latices, where the main characteristic is their homogeneous stability (determining their "shelf-life") due to the "binding power" of the emulsifying molecules toward both the water and grease incompatible phases. The unit structures involved in the phenomenon (emulsifying action and formation of a stable emulsion) are two: the chemical system of M (M_k = "set or population of the components", in which is present the emulsifying or surfactant chemical species S, the components assembled in the "fat or oily" emulsified phase O, the electrolytes and the molecular substances dissolved in the aqueous phase W) and the colloidal chemical-physical system of M, constituted by the emulsion (M_k = colloidal "dispersion", whose simplified model is an homogeneous ternary mixture of the components O/S/W). The considered property is a complex property, whose two different aspects need to be jointly considered. A) the emulsifying effectiveness is an intrinsic molecular property of the chemical species S, joined to its "amphiphily" or affinity to both the oily-fat and water phases that the molecule has to make compatible and to keep "bind". This property of S is measured by its HLB index (HLB= hydrofilic/lypofilic balance) that is computable with a semi-empiric law when its chemical structure is known, with the contribution of both the functional molecular groups present in it: HLB = 7 + ($\Sigma H_i + \Sigma L_i$) where 7 is a conventional value accepted for a molecule with hydrophilic and lyophilic parts perfectly balanced; the terms H_i, L_i are valuable by the expression $an - bV$, where n is the number of molecules of the solvated water, expression of its hydrophylity, and V is its molecular volume calculated by covalent radius, "diluting" factor of hydrophylity and, in this way, representative of the hydrophobic constitution. The hydrophylity must prevail to guarantee the emulsifying action O/W; so HLB must be >7 and practically included between 8 and 18. For example, for the sodium stearate molecule $C_{17}H_{35}COONa$, with one group $-COO^-Na^+$ and 17 groups $-CH_2-$, is possible to calculate an HLB = 7 + (19.1 + 17(-0.475)) = 18, that is a border top value of emulsifying action. B) The forming conditions of a stable emulsion are identified considering it a chemical-physical system whose state (thermodynamic) is described by the respective ternary phase diagram (Figure 4c), where (T, n_S, n_W, n_O) are the state variables and we can distinguish these existence fields: α = O/W stable emulsion, $\alpha + \beta$ = stratified biphasic system where the emulsified phase O/W is accompanied by an oily phase with dispersed water O_W (or where the phase W/O is accompanied by the phase W_O), β = W/O stable emulsion.

expresses a first “black-box”, phenomenological sort of the L_j *behaviour law* of the system, representing only its macroscopic behaviour without considering its inner-structure particularities (IN = cause of the transformation, OUT/ACC = produced effect; n = 1 linear correlation, n≠1 non-linear); for example law of the optical transmittance $I = TI_o$, law of the elasticity $\sigma = E\varepsilon$ etc.[2] (I = OUT, σ = ACC; κ_j = T, E *system-parameters* or system “constitutive properties”). The κ_j constants of the system (independent) and its “critical” characterising T, P, n variables (dependent), that are real evolution-causes named state-variables conditioning the $\kappa_j = \kappa_j(T, P, n)$ values identify instead with its *inner* variables; instead outputs and accumulations OUT/ACC are its “contingent properties”.

EXAMPLE 4. Impermeability of a membrane (tissue). This is a functional property of the high-performance wear textiles, e.g. the “gore-tex” ones, imparted by microfibers, that interwoven forming micropores, and by special surface materials or treatments. The unit structure involved in the phenomenon (repulsion of the “aqueous” phase in contact with the object, obtained thwarting the wetting or superficial W/S contact) is the capillary system of M (M_k = “set or population of pores, canaliculi and micropores”). Its critical properties are the medium diameter D of pores and its superficial hydrophobicity, indirectly measured by the contact angle θ between the membrane material S and the water W (system S/W, see Figure 4d). We assume the tissue make by an hydrorepellent material, so the water retires to its contact (e.g. θ =110° at T= 20 °C) and D = 2 µm. We can foresee impermeability properties verifying the penetration power (= crossing) of the liquid water, beginning by the wetting the material. Being θ >90°, the water contact with the porous system of the tissue generates a capillary lowering Δh and a relative capillary depression p, that opposes to the water penetration (“constraint”), equal to $p = \rho\Delta h = 2\tau \cos\theta/R$ according to the Jurin’s law. With a medium radius $D/2$ = 1 µm =10^{-4} cm, we can calculate a capillary lowering of 2(72 dyn/cm) × cos(110°)/(1 g_p/cm^3)(10^{-4} cm) = 2(72 10^{-5} N/cm) × (-0.34)/(1×9.8×10^{-3} N/cm^3)(10^{-4} cm) = -500 cm, equal to a pressure of 500 cm-H_2O. The tissue can support, without crossing, a water column of 5 m (= impermeability until this deepness). In the considered microphysical system, the influence of the state variables of the system (chemical components S and W, temperature T) is showed by the dependence of the contact angle $\theta = \theta_{SW}(T)$.

The state and the macroscopic properties λ_j of the body or material system (S holistic viewpoint) can therefore be put in the following general forms:

$S = S(T, P, n)$ whole body system
$\lambda_j \equiv (\kappa_j, \text{OUT/ACC})_{T,P,n}$ whole properties (constitutive, contingent)

being, more exactly, (T, P, n) the thermodynamic tern of the state variables temperature, pressure and composition, characterizing the system and therefore all its properties. Answer to stimulus can be instantaneous (e.g. elasticity) or delayed (e.g. viscoelasticity); in the latter case the system reacts to the stimulus modifying its structure and reequilibrating (adaptation) acquiring a more or less fast *motion* toward a new *quiet* steady status (transformation or $\Psi_{12} = \Psi_1 \rightarrow \Psi_2$ state change). Thus a second sort of behaviour laws deals with both the “equilibrium-states” and “transformation-states” of the system:

- time-independence, *statics*: structure stability or constancy of the populations $N_k = (N_A, N_B, \ldots)_k$ of its sub-systems or homogeneity of the space distribution $I(P_{xyz})$ of its energy parameters I, described by permanent and so algebraic equations of ratios of constants quantities, e.g. N_A = const, or simpler S-A identity equations

$S = \text{const} = S_o$, $M_k = \text{const} = (M_k)_o \ \forall\ t \geq 0$ stability,
$N_B/N_A = K_N$; $I_S = I_A = K_I$ equilibrium; *statics*

- time-dependence, *dynamics*: transient evolution of state, described by instantaneous and therefore differential rate-equations, e.g. $(dN_A/dt)_t$ or $(dI/dt)_t$ for the rate at a given instant t being $N_A = N_A(t)$ or $I = I(t)$

$S = S(t)$, $M_k = M_k(t)$ transformation,
$|dN_A/dt| = kf(N_A)$; $|dI/dt| = kf(I)$ non-equilibrium; *dynamics*

where N_A, N_B = populations of the material components A, B of the system (= “quantities” of molecules, phases, microorganisms etc.) and I = energy intensity parameters such as temperature T, stresses σ-τ in the solid body, flow-rate v in the fluidinamical body etc.
For example $N_B/N_A = K_N$ and $dc/dt = kc^n$ for the equilibrium/rate of a chemical reaction A → B (K_N = equilibrium constant, k = reaction rate constant), $T=K_I$ and $dT/dt = k\nabla^2 T$ for the equilibrium/rate of the thermal transport (K_I = uniform temperature, k = thermal diffusivity constant). These equations are strictly associated, respectively, to such graphical representations as the *state diagrams*[3] and the *kinetic curves* are. In these two different cases, any system Ψ_{12} transformation is represented respectively as its “trajectory” and “movement”, i.e. $\Psi(T, P, n)_1 \rightarrow \Psi(T, P, n)_2$ and $\Psi(t_1) \rightarrow \Psi(t_2)$.
A third particular state is the “dynamical steady state”, where N_k-I values are subject in S to local constancy but space heterogeneity, i.e. $I = I(P_{xyz})$ and $I(P_{xyz}) = K_I \ \forall\ P_{xyz} \in S$. Both stationary and kinetic conditions of a system (i.e. equilibrium or dynamics) can be described by: a) *deterministic* models (algebraic/differential) in any “regular” provisional or certainty case, as just considered; b) *indeterministic* models (statistical equations based on frequencies or probability laws, e.g. Poisson distributions of less-frequent or rare events) in any “anomalous” unprovisional, uncertainty, chaos or risk case:

$N_x'' = ae^{-bx}$ b > 0, $N_x'' \equiv P_x'$

where N_x'' = frequency density of the distribution or probability density P_x' and x = observed S statistical variable. Such $N_x''(x)$ distribution curves can describe both stationary and dynamical states[4], respectively in the form of microstates distributions (x = size, energy etc.) and kinetic curves ($x = t$, ageing time). Other examples of indeterministic kinetics concern the sudden collapse or self-growing of the system[4].
Other system-laws are those L_{jk} “*structural*” ones, where both constitutive or contingent properties $(\kappa_j, \text{OUT/ACC})_S$ are correlated to real structure-parameters φ_k of the system, as for example composition (components concentrations) and morphology or energy characteristics of the populations of its sub-systems M_k:

$\kappa_j = \kappa_j(\varphi_k)$ or $\text{OUT} = \text{OUT}(\varphi_k)$ and $\text{ACC} = \text{ACC}(\varphi_k)$ structure laws

Examples are the viscosity law of suspensions or $\eta = \eta_o(1 + bx_B)$, being x_B the particle concentration and b its form coefficient, or the capillary rise law in a porous body or $\Delta h = 2\tau \cos\theta/\rho R$, being θ the water/solid contact angle and R the mean pores-radius, etc.[4] The microstructure parameters contribute to the morphological or iconic description of the several system sub-structures (e.g. covalent radii, cell constants, cristallinity degrees, mean particles radii etc.).

Besides φ_k parameters, also the values of the (T, P, c) state variables that appears in the phase and other state diagrams as critical Y^* system characteristics (e.g. phase-transition temperatures $T_{\alpha\beta}$, eutectic or solubility x_E, x_S concentrations, isoelectrical points IP, stresses at limit elasticity σ_e or break σ_r) and the kinetic constants k, represent structure and behaviour characteristics of the system related to some specific its sub-structures (M_k reductionistic viewpoint):

$$\lambda_{jk} = (\varphi, K_N, \mathrm{k}, Y^* \ldots)_k \qquad \text{structure/behaviour properties}$$

The morphological description of the system at equilibrium, concerning both the structural and energetic state of its sub-structures, is showed by the distribution curves of their characteristics (e.g. sizes or energies: polymers molecular weight, colloids diameter, molecular kinetic energy etc.) or their space-distributions represented as bidimensional maps in the inner sections of the considered "objects" (electron density in molecules, concentration profiles in bodies etc.) or 3D vector diagrams in different directions. Also iconic models $\mathtt{I}(M_k)$ of the various M_k sub-structures contribute to give schematic idealized imagines of the system structure and microstructure.

Both the behaviour- and structure-laws are properly L_j-L_{jk} *system-laws* involving λ_j-λ_{jk} system properties, that really unify the technological behaviour of the several unit structures, as true isomorphisms among different systems as stated by the System Theory. That allows to obtain an *horizontal transfer* of concepts and models among the different disciplines, and so their *comparative* approach.

Iconic models and internal communication of the sub-systems: "unit structures" and "unit interactions"

The unit structures approach [4] characterizes systematically the organization of the body-system or material-system into populations of molecules, colloids, composite histological elements, micro- and macrophases and finally material contiguous points forming the inner continuous "substance" and the external form or system-wall (boundary). In particular we can recognize 5 classes of fundamental unit structures (Table 1) that are related to the contents and models of the 5 basic Disciplines of any technology: Chemistry, Physical-Chemistry, Biology (Cytology, Microbiology, Histology), Physics and Engineering.

EXAMPLE 5. Hygroscopicity. It is a fundamental property governing the water content and so the water-activity value of the material, that influences directly the net water availability by the both chemical reactions in the matrix and biochemical reactions in microorganisms (chemical, enzymatic and microbial deterioration rates); determines also the legal water contents, revealing improper water additions (e.g. 11% limit-value for cereal products). The unit structure involved in the phenomenon (adsorption) if the surface of M exposed to the external environment and therefore interactive with it, i.e. the chemical-physical system of M, made up by the surface layer of the components of the body S and by the AW layers adsorbed from environment (M_k = film or bi-dimensional colloid of the surface components S constitutive of M and of the adsorbed ones: water W and other gaseous components A of the dry air). A model even more simplified is an heterogeneous biphasic system S/W, in which the critical component W shares out between the air phase (= gaseous mixture A) and the solid phase S, whose state is described, as chemical-physical (thermodynamic) system, by its distribution diagram or isothermal equilibrium curve S/W, in which (T, P, n_w, n_S, n_A) are the state variables (Figure 4e). This curve, representative locus of the equilibrium states of adsorbed solid (wet S_w), divides the two non-equilibrium fields of the over-adsorbed (over-wet, S_w + W) and the under-adsorbed (under-wet, S_w') solid. For a material with known composition S exposed to a known air A (P, n_S, n_A fixed constant quantities), if we specify as $(c_w)_S = U$ and $(c_w)_A = \rho_w$ (U = humidity of M, ρ_w = hygrometric degree of A) the water concentrations in the two phases, the system state variables are reduced at (T, U, ρ_w). For the usual bio-organic products, for example wood, leather, foods, at the usual thermo-hygrometric conditions (20 °C, $\rho_w = 0.65$) we observe U values of 12-16%, according to the S composition (hydrophily degree).

Communication among the several classes of unit structures, and among the unit elements of a given class, is represented by their *interactions* (= links, bonds). Formation of these bonds actuates the transmission of the *informations* for the system autorganization. In the progressive passage micro → meso → macro such informations, contained as "chemical message" in the structure of the molecules that are progressively aggregated, are transferred in cascade and progressively compressed in the structures of higher level. Changes of interactions ΔH (= energy) and informations $\mathrm{I} = -\Delta S$ (= order, neg-entropy) in the systems are fundamental thermodynamical properties of transformations. It is possible a physical classification of these interactions in terms of *unit interactions* I_k, or classes of different primary and secondary bonds (ionic, covalent, van der Waals, capillary forces etc.).

Thus in any matter system, communication and information are specifically committed to the chemical sub-system of S at the boundary or interfacies of other chemical sub-systems.

The complexity image of a biological "body-system" is thus its *morphology* or *morphological* system, given by the

Table 1 - Main classes of unit structures (from [4])

- populations of molecules involved in any description of the chemical transformations or *chemism* of the system, considered as in their microscopical aspect of functional chemical units as in their macroscopical aspect of components $(\ldots n_p \ldots)$, and populations of phases $(\ldots \phi_m \ldots)$, that together form a *thermodynamical system* with state-variables (T, P, n);
- populations of colloids in their various morphologies (polymers, gel, sol etc.) and cells;
- populations of microorganisms $(\ldots N_S \ldots)$ and structural cells;
- populations of tissue-elements, considered as both morphological and composite elements;
- populations of the material points $(\ldots \mathrm{P}_{xyz} \ldots)$ of the "continuum" widespread body, a *physical-mechanical* system including the deformable solids (elastic, plastic), the viscous fluids (newtonian, non-newtonian) and the permeable bodies (to matter, heat, various forms of energy).

ordered set of its structure elements of the first four classes of unit structures reported in Table 1 and their reciprocal interactions. I.e. chemical (molecular, macromolecular), histological (biological unities: supermolecular associations, cells, tissues) and physical elements (micro- and macro-phases), ordered by means of the inclusion relation $\subset$ from the lower, inferior levels to the superior ones (levels hierarchy):

$S = \{\ldots M_k\ldots, \ldots I_k\ldots\} = \{M_a, M_b, \ldots, I_a, I_b,\ldots\}$ *morphological* system

$M_a \subset M_b \subset \ldots; a < b < \ldots k\ldots$ sub-systems hierarchy

EXAMPLE 6. Sensorial properties. They are interaction-properties between the body-system and the "sensor-man" system, therefore are typical customer properties. The stimuli deriving by the body-system M (IN) are accumulated in the man-system (ACC) as answers or sensorial intensity *I* felt by the human body, appreciable as levels of perceived intensity on empirical scales (e.g. 0 = not feeling, 5 = extreme). The possible unit structure of M, involved in the phenomenon, can be its surface exposed to environment (colour for "sight", wrinkleness/greasiness for the "touch"), its concentration of particular critical components S present as molecules ("smells" for the "smell", "tastes" for "taste"), as powder (granulation), or again all the continuum *S* (rheologic or mechanical strain properties to suction, mastication, foot wearing, wearing); i.e. chemical, chemical-physical or physical systems of M. General model of correlation is the experimental psychological law of decreasing marginal increases, or Stiven's Law (Figure 4f), $I = k(c - c^0)^n$ where c^0 is the threshold concentration of the feeling (= molecules, particles, cohesion bonds etc.).

Symbol $\subset$ identifies with M_a/M_b interactions, whose intensities can justify or not the ideal $S \cong M_a$ reductionistic hypothesis. Obviously this structural, "static" system description, has to be coupled with the *behavioural* one previously introduced, both static (equilibrium states) and dynamic (non-equilibrium states). Morphological state, as pointed out before, is described by the distribution curves of the dimensions of the structure elements, their maps in the space displaying locations or vector diagrams deploying properties anisotropy. Finally, besides microscopic particles kinetic energies (atoms, molecules, colloids sub-systems), unit interactions contribute as potential energies coming from the I_k mutual forces (bond = spring-oscillator I_k analogy) to the *internal energy* of the system:

$U = \Sigma I_k + \Sigma(\Sigma 1/2mv^2)_k$ system energy

U microscopic changes involving breaking, new formation or simple tension of the I_k bonds, are strictly correlated to the *S/A* energy macroscopic exchanges as heat of chemical and sorption trasformations, viscous flow, medium-friction etc. or works of elastic deformation, surface change etc.: $\Delta U = Q + W$.

The micro/macro unification

Thus we can recognize in any technological body the two basic structural systems of the phases-components $(\ldots\phi_m\ldots, \ldots n_p\ldots)$ and of the continuum of points $(\ldots \mathrm{P}_{xyz}\ldots)$, i.e. those *physico-chemical thermodynamical* and *physico-mechanical* ones:

$S = (\{\ldots\phi_m\ldots\}, \{\ldots n_p\ldots\})_{T,P}$ thermodynamical system

$S = (\{\ldots \mathrm{P}_{xyz}\ldots\})_{T,P,n}\ \mathrm{P}_{xyz} = \mathrm{P}(x, y, z)$ continuous system

both defined by the particular $(T, P, n)_i$ values of the state-variables and that have particular characterising importance toward the system behaviour. In fact they govern all the properties of the other unit structures, that are just composed by molecules and material points; therefore in the "polymorph coil" of any technical behaviour, these systems represent the "leading wire" of the "to be" and "to became" of bodies. Their importance is to be involved in the body-surroundings *S/A interaction*, i.e. to relate the body state and progress to the external perturbations active at the boundary: thermal (*T*), mechanical (specific forces $P = F/\mathrm{A}$; A = surface area), chemical (specific quantities or concentrations *c* of the moles *n*), energetical in the form of fields (specific forces $\mathcal{I}_\Phi$ coming from a potential Φ: electrical E, magnetic H, gravitational G etc. potentials). Naturally in the case of the dynamical state, we observe a state dependence also on the "time" external variable, indicated as

$S = S(T, P, n; t)$ dynamical system

So the considered approach carries automatically two others ones, recurring in every technological description of processes, where we operate the transformation of the both structure and body-form of a material from an initial *state* to a final one.

- the *thermodynamical* or "(T, P, n)" approach, that allows the unity of treatment of the chemical, colloidal, physical and microbiological systems coexisting in the product and their both state (structure) and transformation (process) properties. In particular, the thermodynamical state *i* of the physico-chemical system, determined by the $(T, P, n)_i$ set of variables:

$\Psi_i \equiv (\{\ldots\phi_{mi}\ldots\}, \{\ldots n_{pi}\ldots\})_{(T,P)I}$ thermodynamical state

is indicated as "representative point" in the corresponding phase diagram (see examples 1, 2 and 3), that is also the analogic simulation model of its behaviour toward changes of the state variables (trajectory Ψ_{12} of the system).

- the *continuum* or "P_{xyz}" approach, that allows us to consider the properties of the product as of a continuous material body of finite wideness, at which walls (*S/A* boundary) are active surroundings actions (= transformation "causes") carrying real boundary crossings (= transformation "effects"). These are the properties connected to the matter or energy fluxes: diffusive (mass or heat transfer *m*, *Q*), fluid dynamical (momentum transfer *mv*) and rheological (transmission of inner "pressures" *F*/A configured as normal σ and/or tangential τ stresses). The state of the solid or fluid systems subjected to mechanical actions, will be therefore indicated as

$S = S(T, P\text{-}\sigma\text{-}\tau, n; \mathrm{P}_{xyz})$ continuous system

clearly signifying that their state is influenced by other forces than atmospheric wall-pressure and by the inner position P_{xyz} of every material point. The continuous system state is properly the *inner state* of the body-system, i.e. expressed in terms of the 3D "space" internal variable or $\mathrm{P}_{xyz} = \mathrm{P}(x, y, z)$ position of every body-point respect to a cartesian outer coordinate system (see Figure 1). The actions external to the system are active at the *S/A* boundary as physical-transport forces (produced effects: *Q*, *m*, *mv* transports) or forces of mechanical transmission acting by walls contact or remote (produced effects: field forces $\mathcal{I}(\Phi) = \mathcal{I}_\Phi$ of various nature, i.e. mechanical σ, τ, electrical E, electromagnetic E-H, gravitational or centrifugal G). In this perspective these actions are generically classified as potentials Φ^5, respectively physical-transport potentials Φ_Z and forces field-potentials Φ_I, that we can think in the *S* interior as due to local Φ_S potentials distributions or fields:

$\Phi_Z = T, c, \rho v; \Phi_I = \Phi_E, \Phi_{E-H}, \Phi_G, \ldots$ transport and field potentials
$\Phi_S = \Phi(x, y, z)_S = \Phi(P_{xyz})_S = \{\ldots\Phi_P\ldots\}_S \; \forall \; P = P_{xyz} \in S$ inner field
$\Psi_i \equiv (\Phi_S)_{(T,P,n)i} = [\Phi(P_{xyz})_S]_{(T,P,n)I}$ field-state (potential Φ)

So we can think about the physical transports J_Z and the specific field forces I_Φ so produced (unitary fluxes), as they are the effects coming from such hypothetical Φ field-potentials (thermal, kinetic in fluids, elastic in solids, electrical, centrifugal etc.) and themselves likely distributed in *S* as vector fields:

$J_Z = Q/At, m/At, mv/At$ specific physical transports
$I_\Phi = \sigma\text{-}\tau, \mathrm{E}, \mathrm{E\text{-}H}, \mathrm{G}, \ldots$ intensity (specific field forces)

In particular, the local transports J_Z operated in *S* can be visualized, in the 3D space, by the internal fields of their potential Φ_Z (e.g. the transport of *Q* displayed from a *T* field). Obviously, in *S* can operate inner potential-fields, and corresponding field-states, whether static $\Phi_S = \Phi(x, y, z)_S$ or dynamic $\Phi_S(t) = \Phi(x, y, z; t)_S$. Naturally, formal relations analogous to Φ_S and $\Psi_i = \Psi_i(\Phi_S)$ hold also for the quantities I_Φ that are in any case related, as manifested effect, to these potentials and that show field distributions (deformations in solids, flow rates in fluids etc.: $I_\Phi = \varepsilon, v, \ldots$).

The inner fields $\Phi = \Phi_Z, \Phi_I$ and I_Φ acting in *S*, so represent its correspondent inner states or *field-states*, thermal, diffusive, kinetic, stressed-mechanical, electro-magnetical etc. time to time induced (warmed body, cooled, migrated, moved or animated stressed, radiated etc.). Properties describable in terms of field-properties define the heterogeneous state of the system in its various aspects; these are all the properties of the heterogeneous bodies, starting from matter concentration or density ρ. The same holds for the *S* sub-systems: e.g. in the molecules set of *S* the probability wave-function of the molecule electrons is a field-property, representing the quantum-mechanical molecule state and its electrons density governing all its chemical properties.

The inner state of the system is represented, as analogic-iconic field model $I(\Phi)$, by the monodimensional "profile" or bidimensional "map" of the given distribution of Φ or I_Φ: a) families of curves $\Phi(x)_t$ for the scalar fields tracing the Φ profiles in proper vertical sections *zx* of the object (see examples 9 and 10) or equipotential level curves $\Phi(x, y)_t$ = const in proper horizontal sections *xy*; b) force lines (of flux) for the vectorial fields crossing the object space, whose space-density is proportional to the local I_Φ intensities.

The inner state of the moved fluid bodies can concisely be related to some numerical indices N that are arithmetical combinations of both constitutive and contingent properties, again related to the state variables, and geometrical *x* boundary-variables related to the container-form and size; for example the Reynolds number $R_e = \rho vx/\eta$ related to the laminar or turbulent motion state of a fluid body in a pipeline of diameter *x*:

$S = S(\mathrm{N})_{T,P-\tau,n;\,x}$ being $\mathrm{N} = \mathrm{N}(T, P\text{-}\tau, n; x)$ fluid dynamical system
$\Psi_i \equiv S(\mathrm{N})_{(T,P-\tau,n;\,x)I}$ fluid dynamical state

Starting from Thermodynamics and Continuum Theory, we can develop:

- the *combined* or "$(T, P, n) \times P_{xyz}$" approach that considers materials as holistic systems of "bodies" of several coexisting structures, jointly exposed to change of the thermodynamical state-variables and so subjected to various their transformations. Therefore this approach can face, in a comparative way among the several unit structures, both the *static* or "structure" complexity of the equilibrium states in any form (chemical, thermal, microbiological, mechanical etc.) and the *dynamic* or kinetic one. This latter can be essentially understood as both parallel and consecutive kinetics involving contemporaneously chemical (reactions), microbiological (birth, rising, death of microorganisms), physical (dispersion of both matter or energy, viscous creep) etc. sub-systems. Such properties thus join together the morphological, static and dynamic properties of both the start and end states of the system, referred to all its sub-structures.

EXAMPLE 7. Microbial degradation. It is a property correlated to the shelf-life; that is to the growing of microrganisms, dependent, from a biochemical metabolic pathways viewpoint, by the chemical characteristic of the body matrix. The unit structure involved in the phenomenon (microbial increase, consumption and degrading transformation of the components of the body) is the microbial system of M (M_k = "microorganisms set or population"), frequently constituted by the common non-pathogen bacteria, yeasts, molds whose microbiological state is conditioned by the state variables (T, n_{w}, n_{salts}, $n_{\mathrm{saccharides}}$, $n_{\mathrm{nutrients}}$, $n_{\mathrm{growth\ factors}}$, n_{H^+}, n_{O2}, n_{CO2}, $n_{\mathrm{anti\text{-}bacterial}}$, …). In this summarized description is implicit, for example, the microbial state dependence on the components that constitute preservation techniques: drying, salting, sugaring, pickling, modified atmospheres, anti-fermentation etc. So the dynamic state of the system, i.e. time evolution of its microbial population N_s described in the growing curve (Figure 4g, intermediate part), is characterized by the latency time t_{L} and by the kinetic constant k_{N} of the growing equation $N_{st} = N_{so}e^{kt}$, system parameters both dependent on the aforesaid state variables, principally on temperature and water activity. After growing, a phase of stationary equilibrium state of population N_s =const (deaths = births) is reached, followed by a decay (deaths > births).

Among the properties that involve both thermodynamical and continuum state-variables in both dynamical and stationary aspects, are the typical Ψ_{12} technological or transformation properties. These latter concern change of the system from an initial raw-matter Ψ_1 state to a final Ψ_2 finished one (e.g. drying, hydration, fermentation, sterilization, heterogeneous chemical reaction or chemisorption etc. of a 3D technical body):

$\Psi_{12}: \Psi(T,P,n; N_s; P_{xyz})_1 \rightarrow \Psi(T,P,n; N_s; P_{xyz})_2$ technological transformation

where Ψ_{12} summarizes both the structure and behaviour properties of the system involved in the transformation

$\Psi_{12} = \Psi(M_k; K_N, \mathrm{k})_{12}$ technological properties

These technological transformations involve consecutive and/or contemporary transports of Q, n_p, N_s (heat, critical active components or microorganisms exchanged, produced or transformed) across the *S/A* boundary and in *S* (external/inner i.e. heterogeneous/homogeneous transports). Thus transport mechanisms involved in transformations can be represented as in series or parallel logic circuits involving the

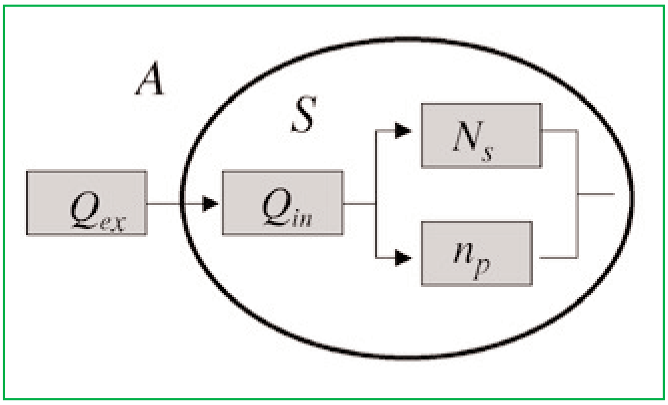


Figure 2 - Logic connection simulating complex technological transformations. Example of microbial sterilization

combined *S/A* systems (Figure 2, example of sterilization involving transports of heat and both microorganisms and active components decay). Our systemic approach comprises in an unique approach both the discontinuum (discrete molecules or particles, microorganisms, ultra-structure elements; microscopicity) and continuum (continuum of homogeneous substance; macroscopicity) aspects of the material. The opposite, dual viewpoints of the traditional micro/macro dichotomy are so considered as alternate faces of the same system-object (syncretic conciliatory viewpoint). Further viewpoint will be considered in the next section.

Interaction between systems

From a technological viewpoint, where we expect to govern the process in order to control the product, is thus established a direct consequential relation, in terms of causality (boundary actions → states of desired structure/properties), between the process-surroundings and the product-system as indicated in the Figure 1. Process and product are systems that come into contact and exchange energy and matter (*S/A* interaction thorough exchanges of *Q, m, mv* or actions of the field potentials Φ_I, that really represent the external communication of the system). We can therefore integrate perfectly the unit processes theory with our unit structures approach, as a mix of correlated and interwoven formal knowledges:

$$\left.\begin{array}{l}\text{process action} \rightarrow \text{system perturbation}\\ \text{process variables} \rightarrow \text{system state-variables}\\ (T, P, n; t)_A \rightarrow (T, P, n; \mathrm{P}_{xyz})_S\end{array}\right\}\ S/A\ \text{interaction}$$

were we evidentiate that the time variable controlled by the process governs the space variable into the product, i.e. the *(x, t)* space-time distributions of Φ_S and $(I_\Phi)_S$ observed in the course of the transformation. If the equilibrium is reached, an S/A correspondence of state-variables is finally stated. The macroscopic *(Q + W)* energy *S/A* exchanges in the course of the transformation, are strictly correlated to the ΔU system microscopic change by the 1st principle energy-balance, as we pointed-out previously. Naturally the *S/A* interaction that we can consider from this view-point is fully general and can be transferred to any life-cycle situation or context of the technological object. For example *A* = surroundings of the process, of the laboratory test, of service or operation, human body envelope, consumer, environment ecosphere etc. *S* = product in the course of transformation, under test, during their working or functioning, as food or drug, as commodity, as sewage etc. Thus we can comprise in our scheme any sort of technological property as well as any functional property related to commodity-science, e.g. organoleptic and physiological, pharmacological, environmental etc. In this scheme we can also recognize technical situations preceding the product industrial life-cycle; i.e. of farming or breeding where the system growing is subjected to both endogenous variables devoted to system autorganization (e.g. originary genetic factors constituted by specific DNA molecules differentiating cultivar and breeds, enzymes and metabolites) and exogenous (environment). These are the typical morphogenesis properties of the raw materials such as biosynthesis, cellular growing and differentiation, tissues assembling, ripening or growing to a commercial size.
In the example 6 are briefly discussed functional (organoleptic) properties, coming from the interaction between the product-system and the “consumer-system” (product-consumer interaction).

The (micro)biological sub-system

Besides inanimate, in bioorganic materials also *animate* sub-systems occur, i.e. those (micro)biological ones formed by the various (...N_s...) microorganisms populations coexisting in the body-system, to which specific attention has to be devoted. In fact any monocellular microorganism can be considered as a (bio)chemical *S* microsystem, opened to matter (...n_p...) and energy (*T*, *P*, ...) exchanges with its surroundings *A* trough the cell wall (see example 7). Surroundings is the body-system aerated matrix, that can be considered as the micro-*eco*system where microorganisms breathe, “catch” their nutrients, compete among them, and can “fall ill” and die from poisoning. Thus we can consider a (*micro*)*biological* state repre-

EXAMPLE 8. Rheologic behaviour. Both mechanical and viscosity properties are fundamental in order to allow technological employment of materials having, time to time, hardness, tenacity, glassy or, on the contrary, softness, elasticity, plasticity, fluidity etc. The unit structure involved in the phenomenon (mechanical stress under a load, with combined effect of strain and break of the inside bonds) is the whole body (M_k = “continuous medium” or “material points set or population” of M), whose analogic model, that simulates its mechanical properties, is the “viscous-elastic body”, made up of a set of springs (“elastic body”) and dampers (“viscous body”) connected either in series that in parallel (Figure 4h); in fact, in the biological bodies are contemporarily present elastic components (polymers) and viscous plasticizying components (water, solutions and water suspensions), so the state of the system is, approximatively, checked by the (T, P-σ, n_w) state variables. The correspondent strain-time diagram (ε-t) shows a trend coinciding with that of the real body; in detail, there is an instant strain for the elastic components and an exponential strain for the viscous-elastic one, with strain initial delay $\varepsilon_t = \varepsilon_0(1-e^{-kt})$ and final release $\varepsilon_t = \varepsilon_0 e^{-kt}$, While elastic strains are instantaneous, the viscous ones need time, so the observed phenomenon has dynamic characteristics and the state of the system is described more exactly as dependent from the variables (T, P-σ, n_w; t), in accord with the principle of overlapping time-solvent- temperature. Nevertheless it is clear that continuum is the unit structure involved in the macroscopic rheological description, whereas chemical (n_p components, l_k bonds), colloidal and composite unit structures are involved in the structural microscopic one.

sented by these (...N_s...) populations whose amounts, ranging from concentrations (specific N_s/w "counts" in weight or area units) of few unities to $10^9/cm^3$, are strictly correlated to their latency, grown and toxins-producing states:

$\Psi_i \equiv (\{...N_s...\})_{(T,P,n)i}$ (micro)biological state

Microbiological input variables, coming from desired inoculation or undesired contamination, thus complete our body-system boundary actions (see Figure 1).

Axiomatic model of the transdisciplinary "technical theory"

The different explanatory proposals that were described in the previous paragraphs, need of an organic arrangement in a framework of preliminary statements, utilization rules and conventional agreements suitable to provide a first qualitative subdivision of the technological reality. Every theoretical construction of technical knowledge, intended as a "method" able to draw and to arrange in a structured way (*systematicity* and *organicity* requirement) the observed technological phenomena and so the knowledge models of technologies, has to be itself proposed as a *model*; that is as a formal logic structure of some preconstituted opinions.

Besides, there are two important criteria to application purposes. The proposed model has to be *simple and versatile*, because technology presents everyday new problems and foresees rapid and continuous applications in different and unforeseeable directions. The model has to act as an "handbook" of recurring behaviours in industrial technologies and to appear as *a management system* of technological information utilizable as general interpretation-key (see next paragraph).

According to these preliminary statements, the presented model is formulated as an *axiomatic* model; that is structured as a logic construction or $\{...P_i...\}$ set of single propositions or primitive enunciations (= hypotheses or axioms) confirmed by the technological experience, of clear comprehensibility and truth, presented in the simple but efficacious symbolism of the sets theory. The value of this framework is of "opportune tool" for a practical use (*pragmaticity* need); that is to be suitable to structure in a systematic way (= to arrange in tables or schemes) the "set" of phenomenological symbolical, analogic and iconic models (= laws, equations, diagrams, idealized structures, mechanisms) formerly put at disposal by the various basic Disciplines. These latter historically elaborated such models in an independent way, and so fragmented, for each individual "class" of materials (chemical components, microorganisms, "physical bodies" etc.). In such a way this unit treatment becomes referable to each of these classes and supplies a first identity of the complexity of every material (structure and complex properties).

We can summarize in Table 2 the statements of our axiomatic model presented in Ref. [4] and translate their in proper symbols. We can so distinguish 3 first characterizing axioms, being the subsequent two more exactly deduced "theorems" or "axioms-corollaries". In fact if we consider the two particular high-characterising sub-systems of the "phases and components" and of the "material points" of the body, we can consider the 4th and 5th statements too. In this way the systems are defined in the complete context of their state or transformation variables: $S = S\,(T, P, n;\, P_{xyz}, t)$. The pattern of these statements represents the embryonal nucleus of a transdisciplinary "technical theory" of biorganic materials, here proposed as model of as iterpretating as operative protocol. Two papers illustrate as foods can be viewed as micro- and macro- body-systems [13, 14], discussing their properties both thermodynamical (state diagrams, kinetic equations) and continuous (equations of transport, as stationary and transient states, and mechanical models).

EXAMPLE 9. Migration in the system ("start-up" or transient state). This event can occur toward or inward the biorganic materials during their contact with their environment constraining walls, and influence their important safety properties; e.g. from packaging to contained foods, from lining to leather handmades, from textiles to human body. The unit structure involved in the phenomenon (matter input by diffusion, from outside to inside through the body-system boundary) is the whole body (M_k = "continuous medium" of M). For simplicity, migration is considered mono-dimensional along the x direction (distance x, point P_x). The concentration c of the component B, migrating from A to S at rate $(\partial c/\partial t)_x$, given, at any point x, by its gradient "spatial rate" $(\partial^2 c/\partial x^2)_x$, is the descriptive variable of this phenomenon, and its analogic model is the set of c vs. x diagrams at any time t (c profiles in S, see Figure 4i). At any time t, we can find out, in S, a diagram of the concentration c vs. the distance x or $c = c(x)_t$, beginning from the S/A boundary, "space concentration profile" at time t (see Figure 4i, left diagram) to which, at any distance x, the concentration c vs. time t diagram or $c = c(t)_x$ corresponds ("concentration profile" at distance x, see Figure 4i, right diagram). At any time and distance, there are two sets of these diagrams. The descriptive variable of the phenomenon is a combined function $c = c(x;\, t)$ with quantitative correlation, given by 2nd Fick's law, between the velocity and the gradient, measured for any couple of variables (x; t) by the two profiles' slopes (Figure 4i). In this physical system, the state variables influence (chemical components B and system S, temperature T) is showed by the dependence of the diffusion coefficient $D = D_{BS}(T)$.

Management model of the structures/properties technological-knowledge based on the presented "technical theory"

If we consider the 1st and 3rd axioms, we can obtain by means of the transitivity property the cumulative corollary-hypothesis $M \cong M_k$, that links the real body to some its enucleated partial model-system or sub-system (M_k). This simple equivalence relation carries the useful concepts of *analogy* between M_k and M and so of behaviour *simulation*. Id est the unit structure enucleated from the whole material context, can be utilized as *iconic* model that can simulate the whole real body; this furnishes an important auxiliary tool in the course of our experimental practice, concerning both interpretative (a posteriori) and predictive (a priori) aspects. Obviously any simulative aspect can take shape when we associate to the iconic model of the given unit structure also its *symbolic* (mathematical laws, equations relating phenomenological variables) and *analogic* models (critical variables diagrams, such as of the state-variables reported in the state-diagrams of the system, or mechanical springs models of molecules or springs/dashpots of whole bodies); these latter are fully described by the Discipline covering the phenomenology associated to the considered unit structure.

In order to find a more direct linkage between the various Disciplines and Technology (between scientific theory and technological practice) and to give a general lecture-key of the technical phenomenon in terms of its scientific models, we therefore

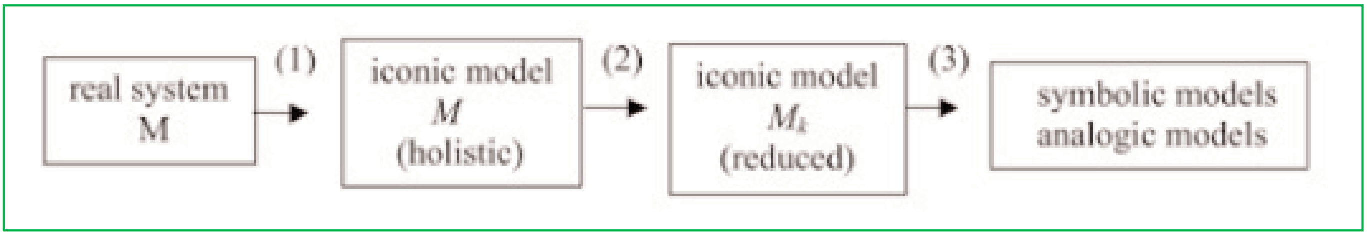


Figure 3 - Block model of managing technical knowledge. Steps sequence in order to interpret the real system in terms of iconic (step 1 e 2), symbolic and analogic (step 3) models

suggest the step by-step procedure reported in the block diagram of Figure 3. Our unit structures-based approach operates firstly in the step 1 together to the systems-based approach (= detailed analysis of the morphology of M and its formalization into its holistic model *M*), and successively in the step 2 (= enucleation of the hypothized M_k sub-structure as being the dominant one involved in the specific investigated phenomenon or property). Step 3 (= association to the M_k sub-structure of its formal, state-of-art models) remains confined in the specific knowledge-field of the various Disciplines.

These steps are involved in the process of interpretation of any real system in terms of its iconic models (steps 1 and 2) or symbolic and analogic (step 3). Step 1 describes the "possible" (deployment of the M_k 's), step 2 extracts the "probable" (focus on a single critical M_k), finally step 3 deduces the "known". Steps 1 and 2 rationalize with a planned method the general as the aimed framework of the investigated fact; step 3 rationalizes its specialistic monodisciplinary insight. The 1→3 sequence is scientific interpretative, that one reciprocal 3→1 is technological operative (we start from some hypothized properties of the body and opportunely modify its structure state so that the desired properties are really obtained in the system).

In order to complete the step 1, can be useful as first complexity-picture the classification-table of the unit structures reported in [4]. In order to complete the step 2 is conversely necessary a general knowledge of the properties and phenomena in terms of materials structures, i.e. an experience of association of these properties and phenomena to the proper unit structures, such as we have already illustrated in the tables reported in ref. [13, 14 and 15].

Simulation and the concept of "unit properties"

In an illustration perspective, the methodological explicative note reported to the end of this paper [7] examines, from this viewpoint and in a comparative way, some properties λ_j of the biological bodies, selected in order to represent significant chemical, physico-chemical, microphysical, microbiological, organoleptic and physical properties related to the correspondent classes of unit structures. Such body properties, viewed in terms of proper unit structures simulating the whole system *S,* have to be therefore considered as *unit properties*:

$$\lambda_{jk} = \lambda_j(S, M_k) = (\kappa_j, \mathrm{OUT/ACC})_S, (\varphi, K_N, \mathrm{k}, Y^*, \Psi_{12} \ldots)_k \qquad \text{unit properties}$$

Unit properties, e.g. freezing temperature, activity of a stabilizing agent, hygroscopicity etc., can be formally described in the same manner for all the matrices (i.e. in terms of the specific proper variables, involved unit structures, models and microstructure parameters) and so independently on any specific class of materials. Finally, the commercial value of a final product is correlated to its quality level *I*, connected to some critical characteristics of the system, chemical (compositions), physical (properties), microbiological etc., that define its "*quality* state" Ψ^*:

$$I = I(\Psi^*);\ \Psi^* \equiv \Psi(\Sigma c_i, \Sigma\lambda_j, \Sigma N_s)^* \qquad \text{"quality state"}$$

The same criteria of morphology and system behaviour that we utilized in order to classify symbolic models, can be now useful for properties classification: of structure or morphological (several system icons or imagines $\mathrm{I}(M_k, I_k, \Phi)$ and system constants κ_j, φ_k, Ψ^*), of behaviour or static and dynamic (several K_N, k, Y^*), mixed of structure and behaviour $\Psi_{12} = \Psi(M_k; K_N, \mathrm{k})_{12}$. The procedure of concepts management summarized in Figure 3 and the axiomatic statements of Table 2 represent so a general guide-line for any preliminary technical analysis to investigate a given phenomenon.

Training

Differentiation of the various Disciplines, already necessary for the learning and knowledge of the *single* aspects of the properties, has to be overcomed when we consider raw materials and intermediate industrial products as bodies subjected to transformation as well as to the investigation by the Applied Technologies.

Training objective for technologists is therefore the joining of the description of the single Disciplines "by watertight compartments" (that singularly cover limited segments of knowledge, *necessary*

Table 2 - Outline of the axiomatic model of the proposed "technical theory" (from [4])

- 1st axiom "the body M is a *system S*" or M ≡ *S*
- 2nd axiom "the sub-systems S_k of *S* are *unit structures* M_k "and their set is the iconic model or "morphological image" of M, or M ≡ *M* = {...M_k...}
- 3rd axiom "the different behaviour and structural properties λ_j of the body M are attributable to only one M_k unit structure or to a restrict number $M_j \in P(M)$ of them" (= *dominant* unit structure or set of unit structures); i.e. *M* properties are "displays" of some M_k selected parts of M_k, or $M \cong M_k$.
- 4th axiom "the body M is a *thermodynamical* system", characterising its thermodynamical state $\Psi_i \equiv (\{\ldots\phi_{mi}\ldots\}, \{\ldots n_{pi}\ldots\})_{(T,P)i}$ and so its both state and transformation properties; or $\mathrm{M} \equiv (\{\ldots\phi_m\ldots\}, \{\ldots n_p\ldots\})_{T,P}$
- 5th axiom "the body M is a *continuous* system" characterising its inner state $\Psi_i \equiv [\Phi(\mathrm{P}_{xyz}, t]_{(T,P,n)i}$ and its flux properties, i.e. of transports, mechanical or field properties; or $\mathrm{M} \equiv (\{\ldots \mathrm{P}_{xyz}\ldots\})_{T,P,n}$

but partial) in an ampler and organized global view, of which the unit structures and unit properties ideas represent a suggested approach. That is as auxiliary tool in order to consider in analytical way any material, handmade or industrial product, enucleating the single component unit structures from the remaining matter context, making so easier the framing of their technical properties into the proper schemes and scientific contents of the various Disciplines. A such construct can constitutes a first basis or platform of dialogue among technologists of different disciplinary training, due to its nature of common denominator devoted to frame and organize any technical scientific knowledge. We have jet coupled also the construct founded on the "system" general concept such as defined by the System Theory, that furnishes the indispensable behavioural thermodynamical basis. This common basis can facilitate communication and so agreement and comparison of the different specialized knowledges possessed by work teams of specialists, in order to face a given R&D problem. The procedures showed in Figure 3 and Table 2 are therefore proposed as a sort of "standard protocol" based on the presented construct, having a value of knowledge managing model or lecture-key of any technological phenomenon by its modellistic tools. The objective is to include the single descriptive disciplinary approaches in a unique planned and all-inclusive method. Finally we can resume in Table 3 the overall opportunities so furnished.

Table 3 - Opportunities of the proposed "technical theory"

- Classify and summarize scientific *models* in the view of pragmatical management
- Confer capability to frame technical phenomena in the complete context of their control *variables*, both thermodynamical and of space-time or (T, P, n), P_{xyz}, N_S/w, Φ_I; t
- Allow the *identification* of simple models in complex systems
- Confer logic and frame to the *multiplicity* of the technological aspects, included in the *holistic* description of the system as totality of its unit structures
- Cover *totality* of the technological properties through deployment of structures
- Actuate an *horizontal transfer* of concepts and models among the various Disciplines (*isomorphism*); that is activate their *comparative description*
- Define the nanostructures actions and properties (*nanotechnologies*) in their full 3D context
- Confer capability of movement and orientation among different subjects thorough plannig an unified method to approach both technological and functional properties as *unit properties*
- Confer sense, identity and planning to the mind-operations, often unconscious, of association of the correct mechanisms to the corresponding properties (*unit properties*)
- Joint the process or the consumer to the product (S/A *interaction*) and integrate the unit-operations theory facing process to materials
- Assure *flexibility* and allow *recycle* of past experience to the new industrial contexts
- Confer *polyvalence*, being referable to the different products life-cycle contexts; i.e. cover *technological*, *functional* and *environmental* as well as *morphogenetic* properties
- Facilitate, on the basis of a common language, the interdisciplinary *communication* among technologists and specialists of different training
- Open to widespread use of *simulation* through mathematical modelling of body-systems
- Open to consider *biotechnologies* from a "bioorganic materials science" viewpoint
- Allow, being based on models, a continuous modular growing by successive steps of the technical knowledge in the course of the entire work life-cycle

Conclusions

The problem of description of properties of bioorganic materials or bodies, starts from the concept of "material-system" or "body-system", that is completely aseptic from any structural and so disciplinary limiting prejudice. Thus this concept seems that one more suitable in order to induce to accept the morphological and so interdisciplinary complexity as a natural and intrinsic definition of these highly-structured materials. This problem can be therefore primarily reduced to a description in terms of "unit structures" and successively to the criterion of selection of that one, or those ones "dominant" versus the different properties.

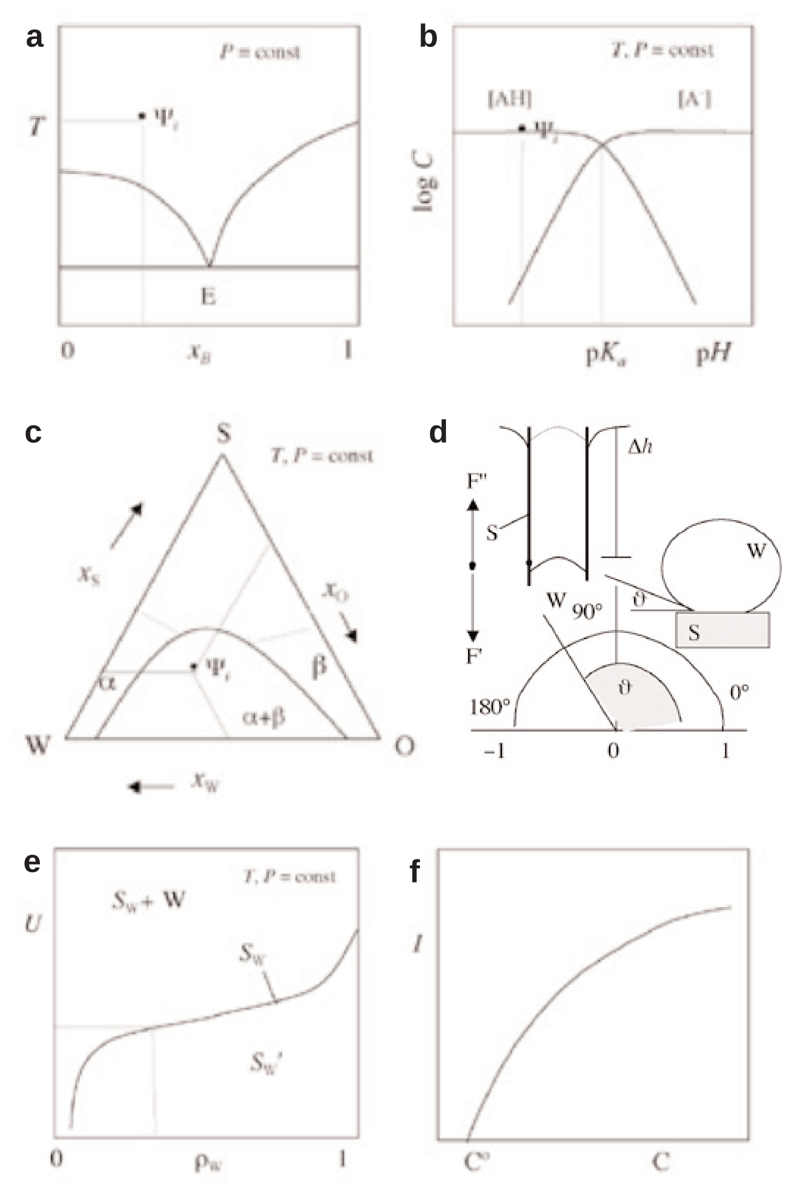
A systematic description of the technological and functional properties in such way, nevertheless qualitative, helps to define a first complexity-frame otherwise appearing as very puzzling. Besides, it predisposes as one' s best to an integrated study of these properties, comprising, as its own logic construct or basic philosophy, the different viewpoint from which the different properties have to be considered. In particular, those knowledge and mind monodisciplinary barriers are so exceeded that oppose to reconcile the micro- and macro- approaches and, more generally, the different viewpoints. Nevertheless such description has to be necessarily companied to that one unified of the behaviour properties, differentiated between statics and dynamics, that only the System Theory can by nature yield. Thus our objective in the brief time is that one of giving a first conceptual knowledge-basis, founded on System Theory, in order to formulate in quantitative terms of laws and mathematical models the modalities of "functioning" of the bioorganic material systems, in the view of optimize their design, control and redesign.

Notes

[1] E.g. concepts of system, parts, interactions-relations among the parts ("links"), organization, hierarchy, surroundings, system state, state variables, equilibrium, stability, property, behaviour, transformation, trajectory (thermodynamical quasi-static Ψ_{12} transformation, state-variables depending), movement (kinetic Ψ_{12} transformation, time depending), isomorfisms, control, reductionism, holism, syncretism etc.

[2] Other examples are the laws of the viscosity $\tau = \eta\gamma$, of the surface tension $W = \tau\,\mathrm{A}$, of the specific heat $Q = m\mathrm{c_p}\Delta T$ (OUT = τ, ACC = W, Q; IN = γ, A, ΔT) and of the energy and matter "streams", where the unitary fluxes or rates of the transported entities Z ($J_Z = Z/\mathrm{A}t$, $r_Z = \mathrm{d}Z/\mathrm{d}t$ or $r_Z = \mathrm{d}\Phi_Z/\mathrm{d}t$; $Z = Q$, m, mv) are re-

EXAMPLE 10. Migration in the system accompained by its “shrinkage” and mechanical stress, jointly observed in any wet-body drying-process (“start-up” or transient state). A proper drying state is a critical condition for all the bioorganic materials, such as foods, paper, wood, leather, in order to assure homogeneity among the inner core and external boundaries, avoiding internal stresses and water pockets that could cause fracture and interior bacterial attack sites. The unit structure involved in the phenomenon (matter input and output by diffusion, from the body-system outside and consequent contraction and stress) is the whole body (M_k = “continuous medium” of M). For simplicity, migration is considered mono-dimensional along the *x* direction (distance *x*, points P_x) and is described as in the previous example (descriptive variable is the concentration of the migrating component W or humidity *U*). We can find out, in *S*, a concentration profile $U = U(x)_t$ vs. distance *x*, beginning from the *S*/A boundary (Figure 4l). The drying occurs by a two step process: 1) humidity transfer to outside; 2) surface evaporation. If the heating conditions make the step 2 faster than step 1, faster surface drying occurs (“crust” formation) while the bulk is still wet. So the drying process induces the contraction (“shrinkage”, strain) of the surface layers, that tighten respect to inside ones (wet, more dilated). Insofar in their movement the formers are “stretched” (tension +) by the inside ones, which they are anchored to, and that, in their turn, are “dragged” (compression -). Then inside the body there is an humidity gradient or distribution $U = U(x)_t$ that produces a strain and therefore a stress gradient $\sigma = \sigma(x)_t$, whose profiles are continuum representations, respectively, of the diffusive and mechanical *S* state at time *t*. From a technological viewpoint, drying process can be considered as a double transport process of heat and matter (water mass m_W), where both thermal and mass internal diffusions and external *S*/*A* wall crossings are involved. Therefore the technological transformation could be visualized as the following consecutive mechanism of *Q*/*m* transports: $Q_{ex} \rightarrow Q_{in} \rightarrow (m_W)_{in} \rightarrow (m_W)_{ex}$ and so represented as a logic in series circuit conceptually similar to that one of Figure 2.



lated to the respective “driving forces” or gradients of the transport potentials Φ_Z (ACC = J_Z, r_Z; IN = $\nabla\Phi_Z$). Streams laws deal with the transport in *S* of the quantities *Z* along its inner distances *x*, that can occur in steady or in transient state according to, respectively, the general laws $J_Z = -\kappa\nabla\Phi_Z$ and $r_Z = \chi\nabla^2\Phi_Z$ i.e. $(\partial\Phi_Z/\partial t)_x = \chi(\partial^2\Phi_Z/\partial x^2)_t$, where $\Phi_Z = T, c, \rho v$ is a sort of “concentration” of the transported entity. In the steady state, the observed fluxes $J_Z = Z/At$ are related to the gradients $\nabla\Phi_Z = \Delta\Phi_Z/\Delta x$, that are constant along the distance and represent the driving forces of the transports, and to the proportionality coefficients κ = k, D, η of conductance, diffusion, viscosity (Fourier, Fick, Newton laws). In the transient state, we can observe transport of heat ($\Phi_Z = T$, χ = thermal diffusivity α; Fourier-Poisson law), of matter of the component B ($\Phi_Z = c_B$, χ = matter diffusivity D_{BS}; 2nd Fick law) or momentum ($\Phi_Z = \rho v$, χ = momentum diffusivity or kinematic viscosity $\nu=\eta/\rho$; Euler law). For the transport of the component B ($c_B = m_B/V$) are observed local fluxes $J_Z = Z/At$ related to their local gradients $\nabla\Phi_{Zx} = -(\partial\Phi_Z/\partial x)_x$ along each of the 3 *x*, *y*, *z* directions and local rates $(\partial c_B/\partial t)_x$ of the B quantities transferred in the point *x* (= transport “effects” or dependent variables) related to their local “space accelerations” or “space rates” of their gradients at the time *t* $(\partial^2 c_B/\partial x^2)_t$ (= transport “causes” or independent variables). Streams laws concerning force fluxes assume the even simpler form $J_I = -\nabla\Phi_I = I_\Phi$. Such relations describe the inner transport in the system; instead across its walls (external transport) hold the phenomenological laws of the “transmission” $J_Z = -\kappa_t\Delta\Phi_Z$ where $\kappa_t = \kappa_t(\kappa)$ is the phenomenological coefficient of the “transport”. Analogous relations hold for the chemical transport; i.e. $J_n = n/Vt = -\kappa c$, where $\kappa = k$ reaction kinetic constant, $Z = n$ moles of the reagent R disappeared and $\Phi_Z = c$ its concentration.

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[3] From our system view-point, we can consider in spread sense as *state-diagram* any equilibrium-state graphical representation concerning a given unit structure: phase diagrams (macroscopical components distributed between phases), log concentration diagrams representative of chemical equilibria (chemical molecular components in the various dissociated, undissociated, com-

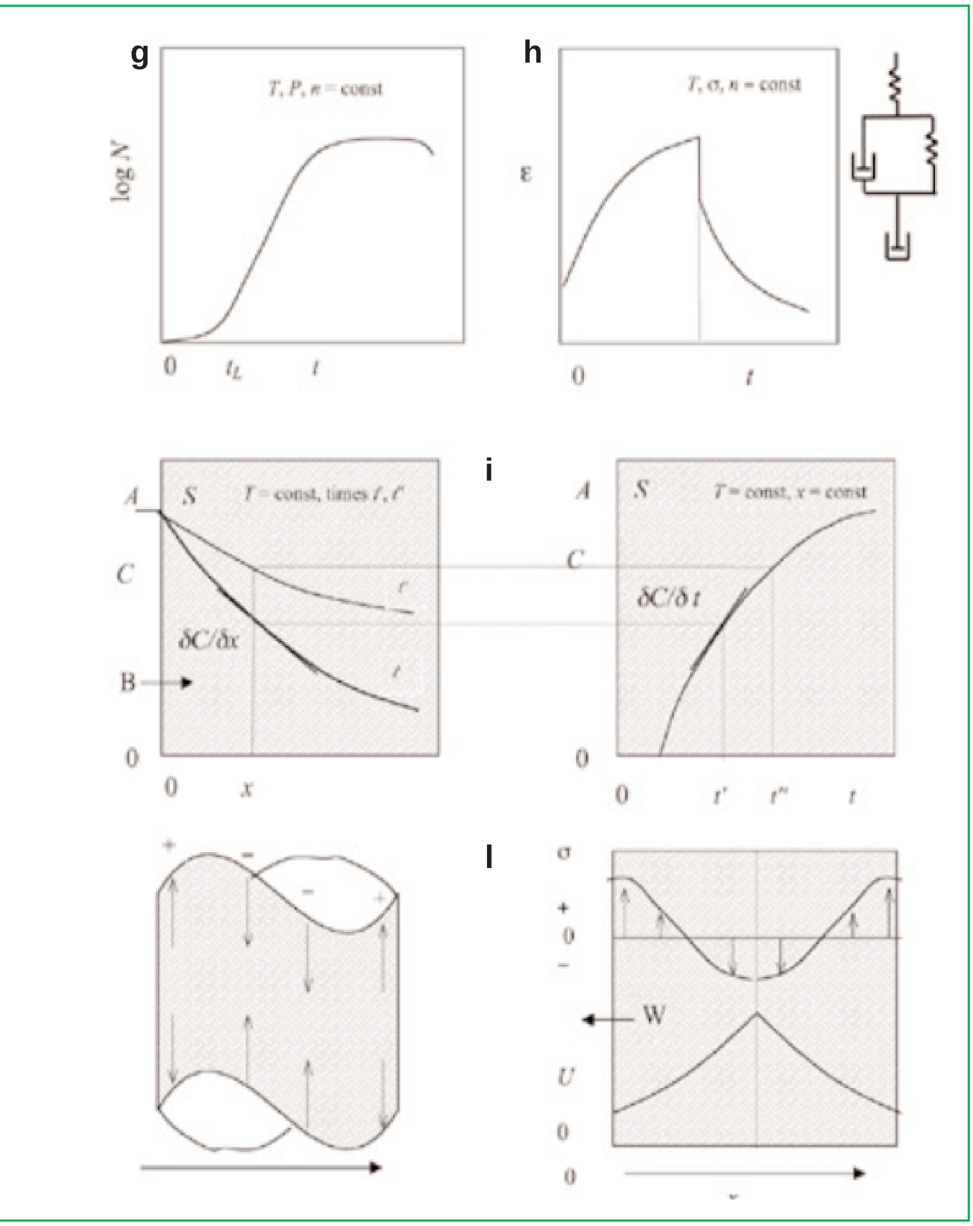

Figure 4 - Analogic models. State diagrams a, b, c and diagram of the equilibrium states e with representative points Ψ_i; iconic equilibrium state d; kinetic curves g, h and i (right hand). Instantaneous field states (of concentrations and stresses) in i (left hand) and l

plexated etc. status), potential-pH Pourbaix diagrams (chemical components in the various oxidation states), titration curves of polyelectrolytes (macromolecular colloids carrying net ionic charges due to ionization respect to their isoelectrical point), isotherms or partition curves, mechanical potential energy diagrams of molecules expressed as a function of the (θ, x) bond angles or distances (molecular conformational states), stress-strain or viscosity-curves (elastic, plastic, viscous, turbulent etc. states), "profiles", maps of distributions or curves of level Y = const of the T, P-σ-τ, c state variables in the inner sections of the material body, such as the mechanical stress patterns (P_{xyz} points of the continuous body with a given Y value, e.g. signifying the internal stressed state), microbial activity diagrams (latency, growing, toxins production, death states), trichromatic Hunter diagrams (chromatic radiating status represented by the (a, b, L) colour coordinates of chroma and luminance) etc.

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[4] Poisson b>1 distributions describe "bell"-type functions of a given system-characteristic in a stationary state centred on the most frequent value (e.g. Maxwell-Boltzmann molecular kinetic energy or colloidal sizes distribution); otherwise 0<b≤1 time-decay distributions describe the ageing of a given system characteristic (first order kinetics concerning concentrations of reacting molecules, dying microorganisms, activated nuclei or molecules etc.). Other indeterministic kinetics concern: a) the sudden collapse of the system under critical variables stressing at the boundary (e.g. O/W → W/O emulsion inversion at a critical x_W composition value); b) the chaotic self-growing or spontaneous organization of the system, due to the reply of a microscopic unit module of nanostructure of constant geometry (e.g. fractal growing of the branched structure of a gel).

[5] Other examples are the Raoult vapour-pressure law or $p_W = p_W^{\circ} x_W$, where x_W is the water molar fraction, the general law of the chemical kinetics or $J_B = kc_A^a$ for the transformation A → B, that correlates the virtual volume fluxes $J_B = (n_B/Vt)$ of the formed components to the reagents concentrations c_A, the law of the correspondent rate-constant of reaction or $k = k_o \exp(-\Delta E^{\neq}_{AB}/RT)$, being $\Delta E^{\neq}_{AB}$ the activation energy of the transformation, the $r_{AB} = r_A + r_B$ covalent radii additivity law, the $P = sD\chi$ gas-permeability law of a polymeric barrier, where s and D are the gas solubility and diffusion coefficient and χ is the amorficity % of the polymer, the $k = a\kappa_t k_c'/(a\kappa_t + k_c')$ global heterogeneous kinetic constant being $a = A/V$ the specific surface area of the heterogeneous porous material, the $Q_{12}/t = \sigma A_1 \xi_{12} (T_2^4 - T_1^4)$ Stefan-Boltzmann law of thermal exchange where ξ_{12} is the shape factor of the radiating and receiving objects depending on their shape, geometrical dimensions, reciprocal orientation etc.

[6] The potentials $\Phi = \Phi_Z, \Phi_I$ are therefore the virtual "causes or primitive driving forces" of the physical transports J_Z or field forces I_Φ, that are both expressible in terms of local gradients $\nabla\Phi_x = (\partial\Phi/\partial x)_x$ of the respective potentials.
Field intensities I_Φ are properly the specific or unitary acting forces (for unit area, charge, mass…: $I_\Phi = \sigma\text{-}\tau = F/A$, $I_\Phi = E = F/q$, $I_\Phi = G = F/m$, …). The fields Φ_S are inner distribution functions of these potentials, continuous in each point of S and therefore defined in both the space (position or point $P_{xyz} = P(x, y, z)$) and time (instant t) if the phenomenon is transient dynamical (body "in course of" thermal, material or momentum supply or removal, i.e. Q, m o mv transport)

$\nabla\Phi_Z = \nabla T, \nabla c, \nabla\rho\ ...; \nabla\Phi_E, \nabla\Phi_{E\text{-}H}, \nabla\Phi_G...$ transports/ field driving forces

$J_Z = -\kappa\nabla\Phi_Z\ ;\ J_I = -\nabla\Phi_I = I_\Phi$ unitary transports/force fluxes

Symbols

A	surface area	Q	heat
c	concentration	r	rate
D	diffusion coefficient	T	optical transmission coefficient
E	elasticity modulus	U	internal energy, humidity
E-H	electrical, magnetic field	v	speed
F	force, free energy	V	volume
G	gravitational field	w	weight
J	flux	W	work
k	thermal conductivity constant	Y	state variable
k, k_c	reaction kinetic constant	γ	deformation rate
k	kinetic constant (general, chemical or physical)	ε	relative deformation
K	equilibrium constant	η	viscosity
I	information amount	φ	system microstructure parameter
I	intensity	ϕ	phase amount
I( )	icon, imagine of	Φ	field/transport potential
$\mathcal{I}$	field intensity (specific force)	κ, χ	transport coefficient (general)
L	law	κ_j	proportionality constant representing the *j* property (general)
n	matter amount as moles number	κ_t	interphase transport coefficient (matter or heat)
N, N_s	number, population, number of the *s* microrganisms	λ_j	value of the *j* property
N	fluid mechanical adimensional number	ρ	density
P	words proposition	σ	normal stress
P_{xyz}	local geometrical point	τ	tangential stress
P	pressure	τ	surface tension
q	electrical charge	Ψ	system state

$I_\Phi = \nabla\Phi_I$; $E = \nabla\Phi_E$, $E\text{-}H = \nabla\Phi_{E\text{-}H}$, $G = \nabla\Phi_G$… intensities or field unitary forces

$\Phi_S(t) = \Phi(x, y, z; t)_S = \Phi(P_{xyz}; t)_S$ field (dynamical)

These transport and forces intensities are vectors directed from higher to lower Φ potential points (sign -). Non-unitary fluxes, crossing perpendicularly a generic dA surface, can be written $J_Z = -\kappa\nabla\Phi_Z dA$ or $J_I = I_\Phi dA$. The transport or field potential Φ, and the related quantities I_Φ, can be point-variables defined as scalars (e.g. temperature), vectors (e.g. the electrical force intensity E in an electrical field, or the velocity in a moved fluid) or operators (e.g. the stresses ‹σ› o ‹τ› or deformations ‹ε› tensors in a stressed body). In the case of the chemical transport, the potential crossing the system is the molar reaction free energy or $\Phi = F$, directly correlated to the concentration of any reaction component by the relation $F_R = F_R^\circ + RT 2.3 \log c_R$. Holds therefore the empirical law of the chemical transmission $J_n = -\kappa_t \Delta F_{PR}$, where J_n is the reagents or products virtual flux, ΔF_{PR} is the chemical potential difference between the reagents and products and $\kappa_t = \kappa_t(k)$ is the phenomenological coefficient of the chemical "transport".

[7] Explanatory note, comparative discussion of unit properties. In the following examined events 1-10, considering P = cost = 1 atm, the tern of the (T, P, n) state variables is restricted at T and a composition … n… limited to the "critical" components for the special considered sub-system (chemical-physical in 1 e 3, chemical in 2, microphysical of porous body in 4 and 5, microbial in 7, physical of continuos body in 8, 9 e 10); water and H^+ chemical species are common critical components of bioorganic systems, affecting concentration-diffusion properties of other components (activity and reaction rates) and acid/base equilibria (ionic charge) respectively. In the event 8 the deforming applied load is added to the atmospheric pressure. The events 1-5 are discussed in static terms, i.e. algebraic equations relating the ratios between the constant quantities of the components, for example $K = n_{sale}/n_w$ in event 1 (lever rule), $K = n_A \times n_H/n_{AH}$ in event 2 (mass action rule) and $K = (c_w)_S/(c_w)_A = U/\rho_w$ in event 5 (partition coefficient) or equilibrium between forces in event 4 (Δh = const, coming from the identity equation $F_{capillarity} = F_{gravity}$). The events 7-10 are discussed in dynamical terms, i.e. of differential equations (reported as integrate forms in the events 7-8 and as differential ones in 9-10) and to above-mentioned variables is added, for characterizing the state, the time variable t. In examples 9 and 10 are considered typical field properties, respectively $\Phi_Z = c$ (Figure 4i) and $\Phi_Z = U$, $I_\Phi = \sigma$ (Figure 4l). In events 1, 2, 3B, 5 and 8 we utilize analogic models (mechanical in event 8), in events 3A and 4 symbolic models, in others both these models (equations and their graphic representations). Figure 4d is an iconic model I(M_k) of sub-system structure and Figure 4l a field imagine I(Φ). The mechanism of the Q/m combined transports in example 10, could be also represented, as analogic model, by a logic circuit in series conceptually similar to that one of Figure 2.

References

[1] C. Peri, L' evoluzione dei concetti e dei metodi della qualità alimentare, Proc. XVIII Congresso di Merceologia, Verona, October 1-3, 1998, 85.

[2] P. Stampacchia, La qualità: fattore strategico nell' industria agro-alimentare, Proc. XVII Congresso di Merceologia, Lecce, October 3-5, 1996, 99.

[3] H. Haken, Information and self-organization: a microscopic approach to complex systems (Ch. 1 and 2), Springer Verlag, Berlin, 1988.

[4] G. Grasso, *Chimica e Industria,* 2002, **84**(1), 43.

[5] J. Monod, Il caso e la necessità, Mondadori, Milano, 1970.

[6] A.D. Little, Report to the Corporation of M.I.T, reported in Silver Anniversary Volume, AIChE, 1933, 7.

[7] D.F. Farkas, *Chemtech,* 1977, **25**(7), 428.

[8] A. Simoncini *et al.,* Approccio ad una interpretazione per modelli dei processi e delle operazioni del ciclo tecnologico conciario, Proc. XI° Congresso Merceologia, Napoli, October 2-5, 1984, 968.

[9] G. Grasso, *Rass. Chim.,* 1985, **37,** 3.

[10] B. de Cindio, G. Grasso, *Riv. di Merceologia,* 1985, **24,** 299.

[11] G. Grasso, *Chimica Oggi,* 1987, **4,** 29.

[12] G. Grasso, *Rass. Chim.,* 1993, **45,** 117.

[13] G. Grasso, *Ind. Alimentari,* 1996, **35**(349), 625.

[14] G. Grasso, *Ind. Alimentari,* 1996, **35**(350), 923.

[15] G. Grasso, T. Scafarto, Le relazioni fra struttura, proprietà e prestazioni tecnico-funzionali dei prodotti a base organica, Proc. XIX° Congresso di Merceologia, Alghero, September 27-29, 2000, 160.

[16] 6th EC Framework Programme 2003-2006, www.cordis.lu/rtd2002/.

[17] P. Eykhoff, Systems Identification, John Wiley & Sons, New York, 1974.

[18] M.D. Mesarovic, Y. Takahara, General Systems Theory, Basic Concepts (Ch. 1), Academic Press, New York, 1975.