A kinetic study of the release of aroma compounds encapsulated in edible films

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I. The encapsulation of aroma compounds into edible films matrices can be an alternative to protect food flavor in food process. Similarly, the release of these volatile compounds during processing or consumption can be controlled. the medium of the release of aroma compounds could be liquid, solid or gaseous, such as foodstuff, beverages or air,respectively. the Release of aroma compounds depend on many factors such as pH, temperature, time etc., so kinetic data can be useful to know the contribution of edible films to the aroma retention of coated food products. Among the methods to encapsulate molecules, Spray-drying a well known technology in the food industry is at the present the most commonly used microencapsulation method for food ingredients.

II. KEY WORDS: EDIBLE FILMS, RELEASE, SPRAY-DRYING

III. NTRODUCTION

Flavor is a combination of aroma and taste components such as sweet, sour, salty and bitter. Beside, flavor is a susceptible component against oxidation, pH and/or reaction with other food components. The rate of release flavor depends on the affinity of the aroma compounds within the food matrix. Encapsulation is a reasonable method for protection of active food components against loss, oxidation or reaction with other food components. (van Ruth et al 2002;),. There are many methods for encapsulation of food ingredients but spray drying is an appropriate and economical method for encapsulation (jafari et al 2008),. The release of volatile components can be controlled via encapsulation (Fabra et al 2012),. Different condition of media such as temperature, water activity, dissolution medium can effect releasing of encapsulated flavors (Fabra et al 2012),. a mixed of ten aroma compound (Ethylacetate, Ethylbutyrate, Ethylisobutyrate, Ethylhexanoate, Ethyl-octanoate, 2-Pentanone, 2-Heptanone, 2-Octanone, 2-Nonanone, 1-Hexanol) was encapsulate in two matrices, one matrice include to only grindsted barrier system 2000 (gbs) And the other one consisted in emulsified film (cg wf). Concerning cg wf films, all the aroma compounds considered were rapidly released from the samples. In the case of GBS sample, aroma compounds concentration decreased slightly with increasing time, for all compounds considered except for ethyl octanoate (Marcuzzo et al 2011),. Encapsulation of n-hexanal and D-limonene within iota-carrageenan and release of them (n-hexanal and D-limonene) was studied in two media, consist of: dissolution medium (water and 0.9% of NaCl) and of the temperature (25 and 37 _C) (Fabra et al 2012),. Vanillin encapsulated in carnauba wax microcapsulates and the analysis of thermal release of this, The data from this analysis can be explained by the Avrami–Erofe'ev kinetic model A3 (Stojakovic et al 2012),.

IV. ENCAPSULATION

Encapsulation is a procces to entrape active agents within wall material. Trapping active agents in the wall material leads to stability of active agents during processing and storage and to prevent undesirable interactions with food matrix. Encapsulation has variety application in food industry. Encapsulation is a suitable method for reinforce delivery of active agents of food (such as antioxidants, vitamins, flavours, minerals, oils) in foods. The most application of encapsulation is for covering of food active agents and protecting of them against physical barrier. Encapsulation is the process of packaging liquid, gaseous, solids materials in small capsules and controlled release of them in variety media.(Nedovic et al 2011),. The choose of suitable wall material is an impotrant step in encapsulation technique. for efficient encapsulation, choosing of the active agents is important step. There are some properties which the wall material should have such as film forming , release the flavour when reconstituted in a finished food product; economical; bland in taste; stable in supply; and afford good protection to the encapsulated flavor (jafari et al 2008),. There are many wall materials with different characteristic for encapsulation. Edible film can carry active components such as flavors, antimicrobial agents and other food additives in the form of hard capsules, soft gel capsules, microcapsules, soluble strips, flexible pouches, coatings on hard particles and others. many methods used for encapsulation like spray drying, spray-bed-drying, fluid-bed coating, spray-chilling, spray-cooling or melt injection(Nedovic et al 2011),. Spray drying is a commonly used for encapsulation of food ingredient. Advantage of spray drying consist of: economical, flexible, rapidly technique, uses equipment that is readily available, and produces powder particles of good quality (jafari et al 2008),.

V. EDIBLE FILMS

Edible films are produced from edible biopolymers and food-grade additives. Biopolymers can carry food ingredients in the form of hard capsules, soft-gel capsules, microcapsules. A variety of food-grade proteins and polysaccharides can be used to prepare biopolymer particles, consist of whey proteins, casein, soy proteins, gelatin, zein, starch, cellulose, and various other hydrocolloids (table1) (Matalanis Alison et al 2011),. Indeed the Edible films are used as wall material for encapsulation of active agents of food. Protect of active agents from undesirable conditions and controlled of release of them are important role of edible films as a wall material. The physical and chemical characteristics of the biopolymers greatly influence the properties of resulting films and coatings. There are many biopolymers such as proteins, carbohydrates, lipids as can be used to create a diverse range of delivery systems suitable for encapsulating (Hun Jung H et al 2005),.

A. Proteins:

Proteins are as combined of amino acids that come in a variety of different general structures (Fig.1), e.g., random coil, fibrous and globular proteins. There are many factors for selection of suitable proteins to fabricat biopolymerbased delivery systems, consist of knowledge about specific physicochemical characteristics of the proteins involved, such as thermal denaturation temperatures (for globular proteins), helixecoil transition temperatures (for gelatin or collagen), isoelectric points (pI), sensitivities to specific monovalent or multivalent ions, or susceptibility to specific enzyme or chemical cross-linking or degradation reactions and establish the electrical characteristics of the protein molecules involved since electrostatic interactions are often utilized in structure formation and must to have knowledge of the nature of the biopolymer particles that can be formed after protein association, such as their morphology (fibrous, globular), physical properties (density, refractive index), size, charge, and stability (e.g., to pH, ionic strength, temperature, and enzymes). These factors will determine how the particles may impact the optical, rheological, stability, and functional characteristics of the products into which they are incorporated (Matalanis Alison et al 2011),.

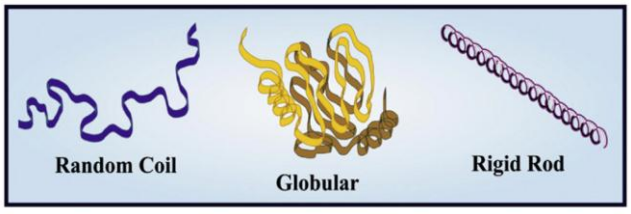

Fig. 1. Simplistic schematic representation of different structures that protein and polysaccharide molecules may have in solution.

Table 1
Summary of important molecular characteristics of food-grade proteins for assembling biopolymer particles. Adopted from Jones and McClements (2010b).

Name	Source	Main structural type	pI	~T_m (°C)
Bovine serum albumin	Bovine blood/milk	Globular	4.7	70–90
Caseins	Milk	Rheomorphic	~4.6	125–140
Gelatin	Animal or fish collagen	Linear	7–9.4[a]; 4.8–5.5[b]	40
Ovalbumin	Egg white	Globular	4.5–4.7	74; 82[c]
Soy glycinin	Soybean	Globular	~5	67[d]; 87[e]
β-Lactoglobulin	Whey protein	Globular	4.8–5.1	75
Lactoferrin	Whey protein	Globular	~8–9	~60 and ~90

[a] Type A gelatin.
[b] Type B gelatin.
[c] S-type ovalbumin.
[d] 7S soy glycinin fraction.
[e] 11S soy glycinin fraction.

B. Polysaccharide selection

Polysaccharides are classified as either homo-polysaccharides or hetero-polysaccharides. Polysaccharides are made of monosaccharide. the type, number, sequence, and bonding of the monosaccharaides within the polymer chain Polysaccharides differ from each other. There are many factors for selection of suitable Polysaccharides to fabricate biopolymer based delivery systems, for institute the environmental and solution conditions where the polysaccharide molecules can associate with other polysaccharide or non-polysaccharide structure-forming molecules, must have knowledge of the physicochemical properties of the polysaccharides involved, such as helixecoil transition temperatures (for carrageenan, alginate, pectin), electrical properties (pKa values), sensitivity to specific monovalent or multivalent ions, or susceptibility to enzyme or chemical reactions, their morphology, density, refractive index, size, charge, and stability to pH, salt, temperature, enzymes and the electrical characteristics of the polysaccharide molecules (Matalanis Alison et al 2011),.

C. lipids

Lipid materials have hydrophobic character and they are good barrier for moisture than polysaccharides and proteins, but they offer little resistance to gas transfer and have poor mechanical strength. But incorporation of lipids in hydrocolloids films increase film hydrophobicity and therefore improve their water vapour permeability.

Table 2
Summary of important molecular characteristics[a] among common food-grade polysaccharides for assembling biopolymer particles.

Name	Source	Main structure type	Major monomer	Gelation Mechanism
Alginate	Algal	Linear	β-D-Mannuronic Acid	Calcium cross-linking
Beet pectin	Sugar beet pulp	Branched coil with protein	Glucuronate (backbone)	Sugar/heat (HM); calcium (LM)
Carrageenan	Algal	Linear/helical	Sulfated galactan	Cooled set
Chitosan	Crustaceans, invertebrates	Linear	2-Amino-2-deoxy-β-D-glucose	No common application
Gum arabic	Acacia sap	Branched coil domains on protein scaffold	Galactose	Conc. dependent
Inulin	Plants or bacteria	Linear with occasional branches	β-D-Fructose	Conc. dependent
Methyl cellulose	Wood pulp	Linear	Methylated glucose	Heat-set (rev.)
Pectin	Plant cell walls	Highly branched coil	Glucuronate (backbone)	Sugar/heat (HM); calcium (LM)
Xanthan gum	*Xanthomonas campestris* exudate	Linear/helical (high MW)	β-D-glucose (backbone)	None; thickens with concentration

[a] Polysaccharide ingredients available commercially generally possess appreciably different molecular and functional properties; the listed information describes general characteristics for industrial usage.

VI. release

Microcapsules consist of the wall materials and core materials. The diffusion of nuclear material of capsules in vitro is called release. Many factors Influence on the release of aroma compounds from the food product. Such as their interaction between food components, mainly proteins, polysaccharide and lipids. Wall materials of capsules e.g., The use of spi for coating of aroma compounds (n-hexanal) as an edible film containing two SPI:LIPID ratios (1:0.25 and 1:0.5), and two types of lipids, oleic acid (OA) and beeswax (BW), in OA:BW ratios 100:0,70:30, 50:50, 30:70 and 0:100 and analyzed of Kinetics of aroma release through the n-hexanal concentration obtained at different storage times, Showed that the development of reduced concentration (Mt/Mt0) of nhexanal vs. time for all the films (fig. 2) and The release rate of n-hexanal is faster for SPI-OA films than for SPI-BW and control (without lipid) films (Monedero et al 2010),. The conditions of release Environmental such as temperature, pH, can affect the release process e.g., In vitro release kinetics of nisin as affected by Tween 20 and glycerol co-encapsulated in spray-dried zein capsules shown the release Increases with decreasing of pH(fig3) (Xiao Dan et al 2011),. Release rate of n-hexanal and D-limonene encapsulated in edible film increases with increasing temperature ((Fabra et al 2012),. The thermal analysis data from Thermal release of vanillin encapsulated in Carnauba wax microcapsules (table 2) can be satisfactorily described mathematically by the Avrami–Erofe'ev kinetic model A3. The Avrami–Erofe'ev nucleation models A1, A2, and A3 take into account. The models A1,A2, and A3 are described by the general equation (1):

$[-(\ln(1-\alpha)^{1/n}]=kt$ (1)

where a is the conversion degree (obtained from the TG measurements) and t is the time. The equation describing the Avrami– Erofe'ev model A3 is obtained for n = 3, and its rearranged form (Eq. (2)) was used in the present work to calculate the rate constant k:

$\alpha=1- e^{-(kt)}$

Eq. (2) was fitted to the experimental data in the a range 0.05–0.95 using a non-linear regression procedure

The estimated values of k, together with the corresponding correlation coefficients of the non-linear regression are given in Table 1. Fig. 3 shows the experimental data for the isothermal vanillin release from wax and the plots of Eq. (2) with the obtained parameter k for the temperatures of the study. The plot of lnk vs. 1/T (Fig. 4) is a straight line. The activation energy calculated from the slope and The Arrhenius pre-exponential constant calculated from the intercept. The low activation energy suggests that for vanillin as the captured molecule, wax is a suitable carrier because it can easily release vanillin when required in the food processing industry.

Table3

Values of *k* obtained for the A3 model (r^2 is the correlation coefficient of the fit).

T (K)	k (min^{-1})	r^2
443	0.0723 ± 0.0006	0.976
453	0.0794 ± 0.0004	0.990
473	0.0868 ± 0.0004	0.993
483	0.0901 ± 0.0005	0.994

VII. concoulusion

There are varity of wall materials used for coating of active compound. edible films such as proteins, polysaccharides and lipids are the most suitable one for coating of active compounds. Controlled release of flavour compound is an important step of encapsulation technique. Release of flavour compound in varity media is influenced by many conditions such as tempeture, pH and time. the thermal release can be in its entirety adequately described mathematically by the Avrami–Erofe'ev kinetic model A3, the course of release is not a single-step reaction but a complex kinetic process.

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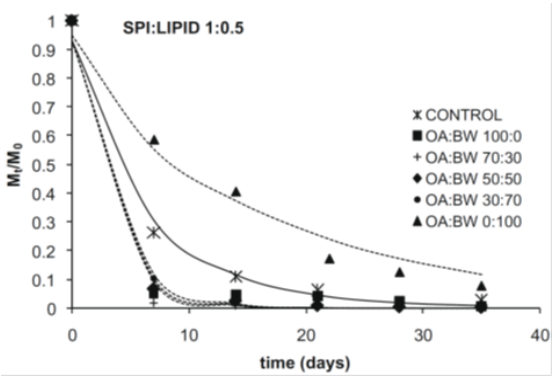

Fig. 2. n-Hexanal release kinetics for the control film and the films containing SPI combind with oleic acid and beeswax in SPI:LIPID ratios 1:0.25 and 1:0.5 (experimental data: symbols, and fitted model: lines).

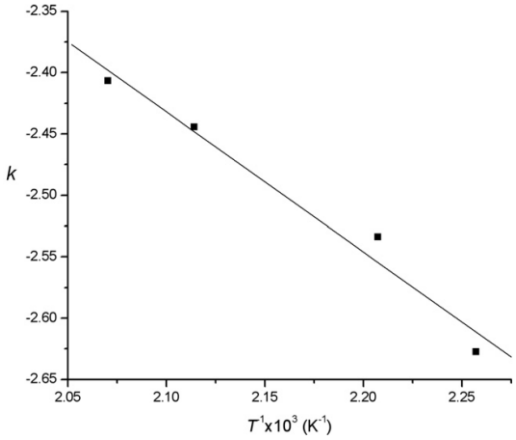

Fig. 3. Plot of lnk vs. inverse temperature for the isothermal vanilla removal.

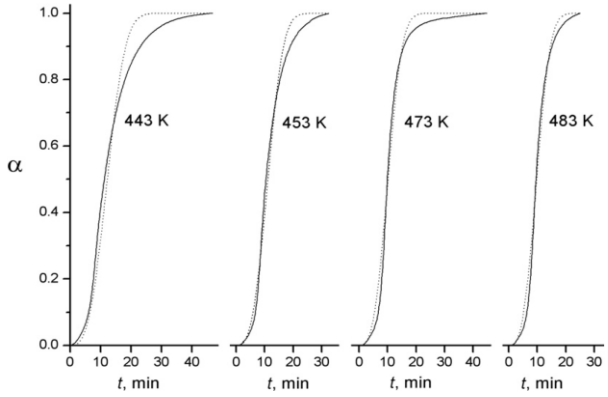

Fig. 4. Plots of the conversion (removal) degree (α) of vanilla vs.time for the studied temperatures [lines – experimental data, dotted lines – plots of Eq. (2) using the obtained parameterk.