

# Laser Raman Spectroscopic Study on Nicotine and Nicotine-Inhibitor Mixtures in Aqueous Solution and the Role of Water in their Taste

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**ABSTRACT:** The role of water in the taste mechanism of small carbohydrates and artificial sweeteners was derived from physico-chemical methods and spectroscopic studies of their aqueous solutions. The effect of bitter substance (Nicotine), Inhibitor of bitterness like Sucrose, Maltitol, Aspartame,  $\beta$ -Cyclodextrin, Na-Gluconate, K-Gluconate and Acesulfame-K or Nicotine-Inhibitors mixtures on water structure was investigated, using Laser Raman spectroscopy in order to enhance our understanding of the role of water mobility in taste perception. The Laser-Raman spectra were recorded in the OH stretching region (3800 to 2800  $\text{cm}^{-1}$ ) and analyzed by comparison to the Raman band of water fitted to 4 Gaussian components. The interpretation of results gives an overall picture of the hydrophilicity, hydrophobicity and water mobility in the aqueous solutions of these molecules. The Laser Raman results seem to be efficient to identify that molecules such as sucrose, Na-gluconate, K-gluconate,  $\beta$ -Cyclodextrin, Aspartame and Acesulfame-K show an antagonist effect to that of Nicotine in ternary water-inhibitor-nicotine mixtures.

**KEYWORDS:** Nicotine; Sucrose; Na-gluconate; Acesulfame-K; Aspartame; density; Laser Raman spectra; taste

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## 1. INTRODUCTION

We have evidenced the role of hydration water on taste perception. The macroscopic properties like apparent specific volume, intrinsic viscosity and Huggin's coefficients have allowed assignment of bitterness to hydrophobicity and sweetness to hydrophilicity of the sapid molecules. The effect of sweetener on the solution property of bitter molecule was attributed to a modification of hydration. The experimental results validated the assumption in designating sweetener as bitterness inhibitor. The mechanism of inhibition of bitterness by sweet molecules may be credited to the increased mobility of hydration water molecules. [1].

Moreover, the results of surface tension [2] have facilitated the classification of inhibitors into three classes namely: molecules with antagonist effect (Adenosine monophosphate) on Nicotine adsorption at the air/solution interface, molecules with negligible effect (Sucrose, Aspartame, Acesulfame-K, K-Gluconate,  $\beta$ -Cyclodextrin) and molecules which enhance the adsorption of Nicotine (Maltitol, Palatinin, Na-gluconate and Furaneol).

In order to understand more about the effect of solutes on water structure we have used Laser Raman (LR) spectroscopy. LR Spectroscopy is known as one of the most appropriate technique to account for the establishing and rupturing of hydrogen bonds in such complex media as water and aqueous solutions. We use it

as a comparative method between pure water on the one hand and aqueous solutions on the other. It was successfully applied to study molecular structure of sapid molecules and their interaction with water [3-6].

As water mobility was found important in interpreting sweet taste chemoreception [4,7,8], Laser Raman spectroscopy of water and aqueous solutions seems to be the most appropriate tool in understanding the role of water structure in taste modalities. The aim of the present study was to investigate the effect of a bitter substance (Nicotine), inhibitors of bitterness like Sucrose, Maltitol, Aspartame,  $\beta$ -Cyclodextrin, Na-Gluconate, K-Gluconate and Acesulfame-K and Nicotine-Inhibitors mixtures on water structure using Laser Raman spectra of these solutions as compared to that of pure water.

## 2. MATERIALS AND METHODS

### 2.1. Chemicals Used

Nicotine supplied by GSK was used without any prior treatment. The potential inhibitors such as Sucrose, Maltitol, Aspartame,  $\beta$ -Cyclodextrin, Na-Gluconate and K-Gluconate were from Sigma Chemicals and Acesulfame-K was a free sample from Nutrinova, France. The chemicals namely potassium dihydrogen phosphate and dipotassium hydrogen phosphate used in the preparation of buffer solution (0.1 M, pH=8.3) were purchased from Sigma Chemicals and were used without further purification.

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## 2.2 Sample Preparation

The samples were prepared in potassium phosphate buffer solution. Before measurements, all solutions were filtered through a 0.22  $\mu\text{m}$  pore Millex Millipore filter. All the measurements were conducted at a constant temperature of 25°C.

## 2.3. Laser Raman Spectroscopy

Laser Raman spectra were recorded with a DILOR model Omars-89 Raman spectrometer, supplied with a multichannel (1024 photodiodes) detector. The monochromator consisted of a grating blazed at 600 grooves/mm and Raman signal detection was done with a two-dimensional (300 x 1152 pixels) CCD apparatus. Spatial resolution was about 4  $\text{cm}^{-1}$ .

Excitation was done by the 514.5 nm line of an Ar<sup>+</sup> laser (model 2065, Spectra Physics) operating at 400 mW. All band intensities were corrected for the monochromator-detector response. Acquisition and treatment of data was done via an appropriate computing system and spectral decomposition was performed by the least-squares method.

## 3. RESULTS AND DISCUSSION

### 3.1. Laser Raman spectra of Water, Nicotine, Inhibitors and Nicotine-Inhibitor Mixtures

Laser Raman spectra of pure water (buffer) was recorded and the Gaussian components of the Raman band of OHs calculated and assigned to different associates of water molecules (monomer, dimer,...). We obtained the spectra of solutes and compared the band of water modified by the presence of Nicotine or Nicotine + Inhibitors mixtures to that of pure water. A deconvolution method of the experimental Raman envelope [3] permitted the identification of the perturbation of water components by the solute. In general, a shift of frequencies towards lower frequencies (negative  $\Delta\nu$ ) are due to an increase in tightly bound clusters of water molecules and a shift towards higher frequencies (positive  $\Delta\nu$ ) is characteristic of more freedom for vibration of OHs, which means an increase of the less tightly bound water species. The change in area of peaks ( $\Delta$  area (%)) accounts for the weight of each of the 4 species (a,b,c,d) of water structure.

To account for the effect of hydrophobicity or hydrophilicity of the studied molecules, nicotine on the one hand, bitterness inhibitors on the other, and their mixtures, on water structure, we have recorded laser-Raman spectra of their dilute aqueous solutions and analyzed them by comparison to the Raman spectrum of pure water (Fig.1). These spectra were recorded in the 3800-2800  $\text{cm}^{-1}$  range. Decomposition of the experimental Raman band was made using a 4-components model of water structure [3]. This model is a basis for the comparison of the effects of each of the

The Laser-Raman spectra of aqueous solutions of nicotine (0.1% and 1% w/v) were recorded in the 3800-2800  $\text{cm}^{-1}$  range and the calculated 4 components (Gaussian) reported in Fig.2 and Fig.3. Table 2 summarizes the effect of nicotine concentrations (0.1 and

solutes on the clustering of water molecules by hydrogen bonds. As it may be observed in Table 1, the four components a, b, c, d are respectively assigned to quasi-crystalline water (clusters of tightly rigid hydrogen bonds ( $0...0 = 270$  pm); solid-like amorphous water clusters ( $0...0 = 280$  pm); liquid-like amorphous species ( $0...0 = 290$  pm) and non associated water molecules ( $0...0 > 300$  pm)).

**Table 1. Position of maximum ( $\nu$   $\text{cm}^{-1}$ ) and % total area and the assignment of the calculated components a, b, c and d of the Raman band of water in the 3800-2800  $\text{cm}^{-1}$ .**

Component	$\nu$ ( $\text{cm}^{-1}$ )	% Total area	Assignments
a	3245	52.2	quasi-crystalline
b	3431	35.5	solid-like amorphous
c	3569	10.5	liquid-like amorphous
d	3650	1.9	unassociated water

The specific effect of nicotine on water structure is given in Table 2. The effect of this solute on the energy of binding of water molecules in the different clusters is manifested by the shift of frequency ( $\Delta\nu$ ) and the proportion of each species is accounted for by the value of the change in total area of band ( $\Delta$  area %).

**Table 2. Position of maximum ( $\nu$   $\text{cm}^{-1}$ ), change in integrated intensities ( $\Delta$  area %), shifts in frequencies ( $\Delta\nu$   $\text{cm}^{-1}$ ) of the four components of water a,b,c,d in aqueous Nicotine solutions at different concentrations.**

Nicotine at 0.1% w/v

Component	$\nu$ ( $\text{cm}^{-1}$ )	% Total area	$\Delta\nu$ ( $\text{cm}^{-1}$ )	$\Delta$ Area (%)
a	3246	51.0	1.0	-1.2
b	3427	35.7	-4.0	0.2
c	3565	11.2	-4.0	0.7
d	3649	2.1	-1.0	0.2

Nicotine at 1% w/v

Component	$\nu$ ( $\text{cm}^{-1}$ )	% Total area	$\Delta\nu$ ( $\text{cm}^{-1}$ )	$\Delta$ Area (%)
a	3238	54.5	-7.0	2.4
b	3427	34.3	-4.0	-1.2
c	3565	9.6	-4.0	-0.9
d	3647	1.6	-3.0	-0.2

1% w/v) on the structure of water. Shifts of frequencies towards lower values are observed for the higher concentration (1%w/v) of nicotine. The same trend is observed for the species b and c at a concentration of 0.1% w/v. The hydrophobicity of nicotine molecules

provokes the strengthening of hydrogen bonding in bulk frequencies for all water species, especially the amorphous clusters b and c. As concerns the change in the proportions of the different water associates, this seems negligible except for a slight increase (+2.4%) of the most rigidly organized clusters (quasi-crystalline a species) in presence of 1% of nicotine.

The experimental Raman spectra of aqueous sucrose solutions (10% w/v) are reported in Fig.4. The effect of sucrose (10% w/v) on water structure is reported in Table 3. The shifts in frequencies observed were remaining within the accuracy of the method ( $\pm 4 \text{ cm}^{-1}$ ). This means that sucrose, because of its hydrophilicity, ( $\Delta$  area) remain comparable to those obtained with nicotine.

**Table.3. Position of maximum ( $\nu \text{ cm}^{-1}$ ), change in integrated intensity ( $\Delta$  area %), shifts in frequencies ( $\Delta\nu \text{ cm}^{-1}$ ) of the four components of water a,b,c,d in aqueous sucrose solution (10% w/v) and sucrose-nicotine (1:2) mixtures.**

Sucrose 10% w/v

Component	$\nu$ ( $\text{cm}^{-1}$ )	% Total area	$\Delta\nu$ ( $\text{cm}^{-1}$ )	$\Delta$ Area (%)
a	3243	53.2	-2.0	1.0
b	3430	35.1	-1.0	-0.4
c	3570	10.3	1.0	-0.2
d	3652	1.5	2.0	-0.4

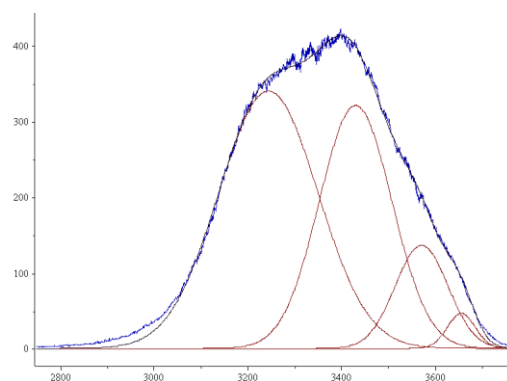
**Table.4. Results of deconvolution of the Raman band of water in presence of the mixtures**

Sucrose 10% w/v + Nicotine 1%w/v

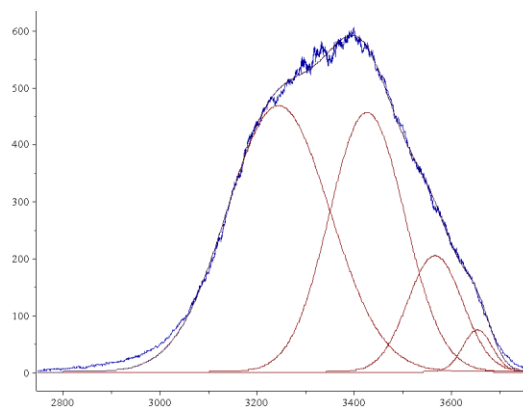
Component	$\nu$ ( $\text{cm}^{-1}$ )	% Total area	$\Delta\nu$ ( $\text{cm}^{-1}$ )	$\Delta$ Area (%)
a	3244	52.4	-1.0	2.2
b	3430	34.7	-1.0	-2.8
c	3565	11.0	-4.0	0.5
d	3652	1.9	2.0	0.0

Laser- Raman spectra of aqueous solutions of Na-gluconate (0.2% w/v) were recorded in the 3800-2800  $\text{cm}^{-1}$  range and reported in Fig.6. The effect of 0.2% w/v Na-gluconate on water structure is summarised in Table 5. Observations of the shifts in frequencies show a contrasted effect. The most rigidly bound water clusters (a and b) display positive shifts (+7, +1) characteristic of a loosening of H-bonds, whereas the less tightly bound associates (c, d) show negative shifts (-3.0, -3.0) very likely due to  $\text{Na}^+$  hydration. The effect of Na-gluconate (0.2% w/v) on the water structure in 0.1%

water and this is at the origin of the negative shifts of fits with the tri-dimensional arrangement of water molecules. Table 4 shows the results obtained with the mixture of 10% w/v sucrose and 1% w/v nicotine. The experimental LR spectra and the calculated 4 components are shown in Fig.5. The observed shifts in frequencies ( $\Delta\nu$ ) are comparable to those reported in Table 3. The effect of sucrose on nicotine solution is to cancel the strengthening of hydrogen bonding due to hydrophobic effect of nicotine on water structure. Only component c, assigned to liquid-like amorphous water remains affected by nicotine. The proportions of the different species of water structures w/v nicotine is reported in Table 6 and the experimental LR spectra are reported in Fig.7. The effect of Na-gluconate on water structure is maintained in presence of nicotine especially for the a-component.



**Figure.1 Experimental Raman spectra of water and the calculated 4 components a, b, c, d.**



**Figure.2 Experimental Raman spectra of aqueous solutions of Nicotine (0.1% w/v) and the calculated 4 components a, b, c, d.**

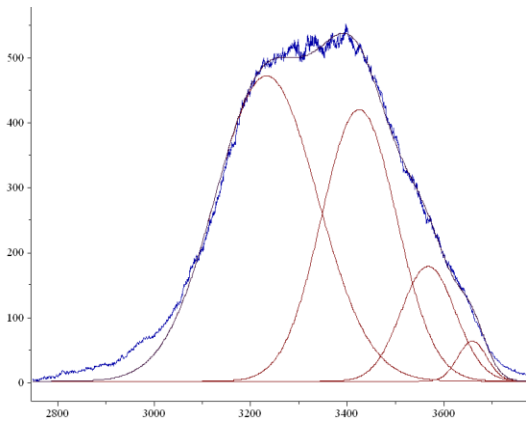


Figure.3 Experimental Raman spectra of aqueous solutions of Nicotine (1 % w/v) and the calculated 4 components (Gaussian)

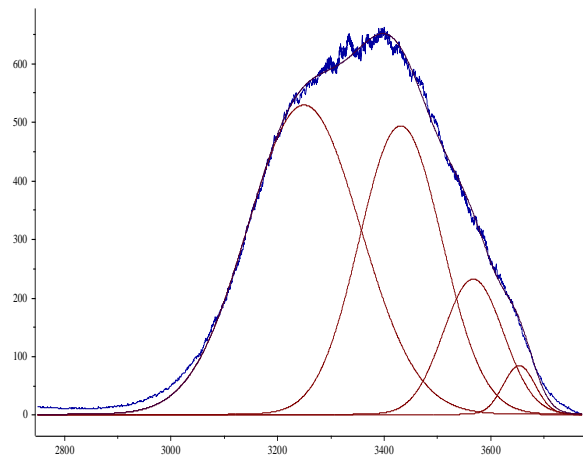


Figure.6 Experimental Raman spectra of aqueous solutions of Na-gluconate (0.2 % w/v) and the calculated 4 components (Gaussian)

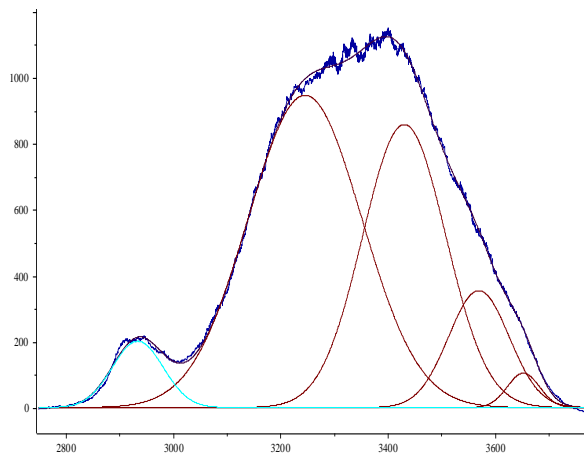


Figure.4 Experimental Raman spectra of aqueous solutions of sucrose (10 % w/v) and the calculated 4 components (Gaussian)

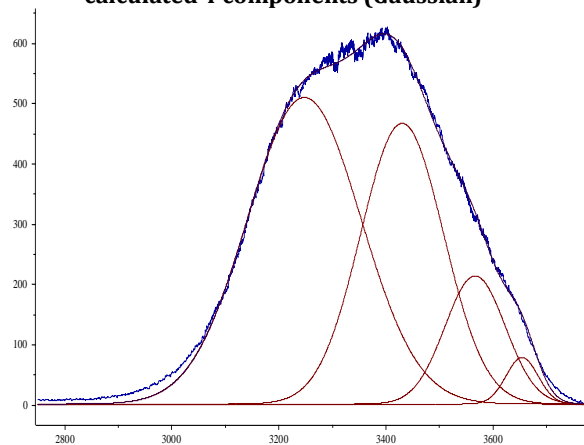


Figure.7 Experimental Raman spectra of aqueous solutions of Na-gluconate + Nicotine mixtures (0.2%+0.1% w/v) and the calculated 4 components (Gaussian)

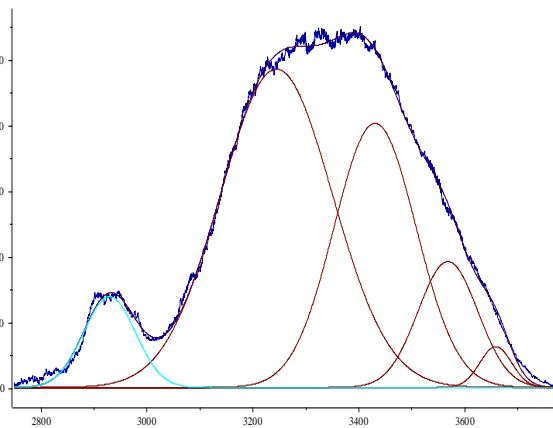


Figure.5 Experimental Raman spectra of aqueous solutions of Sucrose + Nicotine mixtures (10%+1% w/v) and the calculated 4 components (Gaussian)

Table.5. Position of maximum ( $\nu_{cm^{-1}}$ ), % total area, shifts in frequencies ( $\Delta\nu_{cm^{-1}}$ ) and in % total area of the four components of water a,b,c,d for of aqueous Na-gluconate (0.2%) and Na-gluconate-Nicotine (1:2) mixtures

Na-Gluconate (0.2% w/v)

Component	$\nu$ ( $cm^{-1}$ )	% Total area	$\Delta\nu$ ( $cm^{-1}$ )	$\Delta Area$ (%)
a	3252	51.9	7.0	-0.3
b	3432	34.6	1.0	-0.9
c	3566	11.3	-3.0	0.8
d	3647	2.1	-3.0	0.3

**Table.6. Results of deconvolution of the Raman band of water in presence of the mixtures**

Na-Gluconate 0.2%w/v + Nicotine 0.1% w/v

Component	$\nu$ (cm <sup>-1</sup> )	% Total area	$\Delta\nu$ (cm <sup>-1</sup> )	$\Delta$ Area (%)
a	3250	52.5	5.0	0.3
b	3431	34.5	0.0	-1.0
c	3565	11	-4.0	0.5
d	3649	2.1	-1.0	0.2

In presence of 0.2% w/v K-gluconate (Table 7) Raman spectra of water show slight shifts towards lower frequencies especially for component a, which means that the clustering of water is maintained and slightly reinforced. However when 0.2% w/v of K-gluconate is added to 0.1% w/v nicotine, the general effect is to restore the structure of water and loosen a little the clustering of the quasi-crystalline component 'a'. This is a manifestation of an antagonist effect to nicotine, so that the structure promoter effect of nicotine is cancelled by the structure breaker effect of K-gluconate (Table 8).

**Table.7. Position of maximum ( $\nu$  cm<sup>-1</sup>), % total area, shifts in frequencies ( $\Delta\nu$  cm<sup>-1</sup>) and in % total area of the Raman band components of K-gluconate (0.2 % w/v) and K-gluconate - Nicotine (0.2% w/v+0.1%w/v) in water**

K-Gluconate 0.2% w/v

Component	$\nu$ (cm <sup>-1</sup> )	% Total area	$\Delta\nu$ (cm <sup>-1</sup> )	$\Delta$ Area (%)
a	3241	58.9	-4.0	6.8
b	3428	39.7	-3.0	4.3
c	3567	1.1	-2.0	-9.3
d	3649	0.2	-1.0	-1.7

**Table.8. Results of deconvolution of the Raman band of water in presence of the mixtures**

K- Gluconate 0.2% w/v +Nicotine 0.1% w/v

Component	$\nu$ (cm <sup>-1</sup> )	% Total area	$\Delta\nu$ (cm <sup>-1</sup> )	$\Delta$ Ar ea (%)
a	3249	51.7	4.0	-0.5
b	3430	35.2	-1.0	-0.3
c	3568	11.1	-1.0	0.6
d	3650	2	0.0	0.2

The effect of maltitol (0.2% w/v) on pure water (Table 9) and on water in 0.1% w/v nicotine aqueous solution (Table 10) shows comparable results. The shifts in frequencies are negative and the changes in component proportions are negligible. The overall effects are assignable to a hydrophobic effect and cannot be opposed to that of nicotine. Tables 11 and 12 report the results of 0.2% w/v AMP and of the mixtures (0.2% w/vAMP+0.1% w/v nicotine). These results are

comparable to each other and close to those obtained with nicotine alone (Table 2). This means that AMP, which is a hydrophobic substance, cannot be proposed to exert an opposite effect on water structure to that of obtained with nicotine.

**Table.9. Position of maximum ( $\nu$  cm<sup>-1</sup>), % total area, shifts in frequencies ( $\Delta\nu$  cm<sup>-1</sup>) change in the integrated intensity ( $\Delta$  area %) of the four components a, b, c and d for aqueous solutions of Maltitol (0.2% w/v) and Maltitol-Nicotine mixtures (0.2:0.1% w/v)**

Maltitol 0.2w/v

Component	$\nu$ (cm <sup>-1</sup> )	% Total area	$\Delta\nu$ (cm <sup>-1</sup> )	$\Delta$ Area (%)
a	3240	51.8	-5.0	-0.3
b	3428	35.6	-3.0	0.1
c	3563	10.6	-6.0	0.1
d	3646	1.9	-4.0	0.1

**Table.10. Results of deconvolution of the Raman band of water in presence of the mixtures**

Maltitol 0.2% w/v+ Nicotine 0.1% w/v

Component	$\nu$ (cm <sup>-1</sup> )	% Total area	$\Delta\nu$ (cm <sup>-1</sup> )	$\Delta$ Area (%)
a	3240	52.9	-5.0	0.8
b	3428	35.1	-3.0	-0.4
c	3565	10.2	-4.0	-0.3
d	3648	1.8	-2.0	-0.1

Beta cyclodextrin (BCD), which has a hydrophobic surface and a hydrophobic core was tested at a concentration of 0.2% w/v. Table 13 shows negligible effect on water structure. On the other hand, adding 0.2% w/v of BCD to 0.1% w/v aqueous nicotine proves to be efficient in cancelling the hydrophobic effect of nicotine. The comparison of results obtained with nicotine (Table 2) and those reported in Table 14 shows an antagonist effect of BCD. Nicotine is very likely complexed by BCD and the overall effect on water structure of the mixture is comparable to that of BCD alone, mainly due to the hydrophilic surface of BCD. (see Tables 13 and 14).

**Table.11. Position of maximum ( $\nu$  cm<sup>-1</sup>), % total area, shifts in frequencies ( $\Delta\nu$  cm<sup>-1</sup>), change in integrated intensity ( $\Delta$  area %) of the four components a, b, c and d for aqueous solutions of AMP (0.2% w/v) and AMP-Nicotine mixtures (1:2)**

AMP 0.2% w/v

Component	$\nu$ (cm <sup>-1</sup> )	% Total area	$\Delta\nu$ (cm <sup>-1</sup> )	$\Delta$ Area (%)
a	3242	51.8	-3.0	-0.4
b	3426	35.4	-5.0	-0.1
c	3565	10.9	-4.0	0.4
d	3648	1.9	-2.0	0.0



**Table.12. Results of deconvolution of the Raman band of water in presence of the mixtures AMP 0.2% w/v + Nicotine 0.1% w/v**

Component	$\nu$ (cm <sup>-1</sup> )	% Total area	$\Delta\nu$ (cm <sup>-1</sup> )	$\Delta$ Area (%)
a	3241	52.1	-4.0	-0.1
b	3427	35.4	-4.0	-0.1
c	3564	10.6	-5.0	0.1
d	3647	1.9	-3.0	0.1

**Table.13. Position of maximum ( $\nu$  cm<sup>-1</sup>), % total area, shifts in frequencies ( $\Delta\nu$  cm<sup>-1</sup>), change in integrated intensity ( $\Delta$  area %) of the four components a, b, c and d for aqueous Cyclodextrin (0.2% w/v) and Cyclodextrin-Nicotine mixtures (1:2)**

Cyclodextrin 0.2% w/v

Component	$\nu$ (cm <sup>-1</sup> )	% Total area	$\Delta\nu$ (cm <sup>-1</sup> )	$\Delta$ Area (%)
a	3245	51.4	0.0	-0.7
b	3429	35.2	-2.0	-0.2
c	3567	11.3	-2.0	0.8
d	3649	2	-1.0	0.1

**Table.14. Results of deconvolution of the Raman band of water in presence of the mixtures Cyclodextrin 0.2% w/v+Nicotine 0.1% w/v**

Component	$\nu$ (cm <sup>-1</sup> )	% Total area	$\Delta\nu$ (cm <sup>-1</sup> )	$\Delta$ Area (%)
a	3248	50.8	3.0	-1.4
b	3430	35.5	-1.0	0.1
c	3568	11.6	-1.0	1.1
d	3649	2.0	-1.0	0.2

**Table.15. Position of maximum ( $\nu$  cm<sup>-1</sup>), % total area, shifts in frequencies ( $\Delta\nu$  cm<sup>-1</sup>), change in integrated intensity ( $\Delta$  area %) of the four components of water a, b, c and d for aqueous solutions of Aspartame (0.2% w/v) and Aspartame-Nicotine mixtures (0.2:0.1%)**

Aspartame 0.2%

Component	$\nu$ (cm <sup>-1</sup> )	% Total area	$\Delta\nu$ (cm <sup>-1</sup> )	$\Delta$ Area (%)
a	3242	51.4	-3.0	-0.8
b	3426	35.7	-5.0	0.2
c	3564	11	-5.0	0.5
d	3647	2	-3.0	0.1

**Table.16. Results of deconvolution of the Raman band of water in presence of the mixtures Aspartame 0.2% w/v +Nicotine 0.1% w/v**

Component	$\nu$ (cm <sup>-1</sup> )	% Total area	$\Delta\nu$ (cm <sup>-1</sup> )	$\Delta$ Area (%)
a	3244	57.4	-1.0	5.2
b	3430	39.4	-1.0	3.9
c	3570	1.2	1.0	-9.3
d	3650	2.0	0.0	0.2

Table 15, summarises the results obtained with 0.2% w/v of aspartame. All shifts of frequencies for the 4 species of water associates are negative. This is assigned to the hydrophobic effect of aspartame which provokes a strengthening of H-bonds in the bulk of water and a decrease in energy of vibration ( $\nu$ ) due to the hindering of OHs stretching. When aspartame (0.2% w/v) is added to 0.1% w/v nicotine aqueous solution, the frequencies of vibration of the 4 components of water remain comparable to those of pure water whereas their proportions have changed. The shifts of the Raman frequencies assigned to the most rigidly organised species (a, b) are increased and that assigned to the amorphous-like component (c) is decreased (Table 16). Although aspartame seems to exert an antagonist effect to nicotine as concerns the energy of vibration ( $\nu$ ), it remains however a hydrophobic water structure promoter as it contributes to an increase in the proportion of the most tightly bound water associates.

The effect of Acesulfame-K (0.2% w/v) on water structure is reported in Table 17. Observation of shifts in frequencies ( $\Delta\nu$ ) shows a higher mobility of water molecules especially in the quasi-crystalline (a) component (+8%). When 0.2%w/v of Acesulfame-K is added to 0.1% w/v aqueous nicotine, the effect on the different species of water clusters is not the same. The most rigidly bound water associates (a, b) are affected by the structure breaker effect of Acesulfame-K while the loosely bound species (c and d) remain influenced by the hydrophobic influence of nicotine.

**Table.17. Position of maximum ( $\nu$ ), % total area, shifts in frequencies ( $\Delta\nu$ ), change in integrated intensity ( $\Delta$  area %) of the four components of water a, b, c and d for aqueous Acesulfame-K (0.2% w/v) and Acesulfame-K-Nicotine mixtures (1:2)**

Acesulfame-K- 0.2% w/v

Component	$\nu$ (cm <sup>-1</sup> )	% Total area	$\Delta\nu$ (cm <sup>-1</sup> )	$\Delta$ Area (%)
a	3253	51.3	8.0	-0.8
b	3432	35	1.0	-0.5
c	3569	11.7	0.0	1.2
d	3651	2	1.0	0.2

**Table.18. Results of deconvolution of the Raman band of water in presence of Aspartame + Nicotine Acesulfame-K- 0.2 w/v + Nicotine 0.1% w/v**

Component	$\nu(\text{cm}^{-1})$	% Total area	$\Delta\nu(\text{cm}^{-1})$	$\Delta\text{Area}(\%)$
a	3248	52.2	3.0	0.1
b	3430	34.8	-1.0	-0.7
c	3564	10.9	-5.0	0.4
d	3647	2.1	-3.0	0.2

From Raman results, we can conclude that the molecules showing antagonist effect to nicotine as concerns the effect on water clustering may be retained as inhibitors. These molecules are Sucrose, Na-gluconate, K-gluconate,  $\beta$ -cyclodextrin, Aspartame and Acesulfame-K. Not all of these inhibitors have the same overall effect. Sucrose hydrophilicity seems to cancel the effect of nicotine on the most rigidly bound species. K-gluconate, because of the structure breaker effect of  $\text{K}^+$  seems efficient in increasing the mobility of water molecules.  $\beta$ -Cyclodextrin chelates nicotine and restores the structure of pure water. Aspartame cancels the hindering effect of nicotine on OHs vibrations, and contributes by its hydrophobic effect to increase the proportion of the more organised water species. Acesulfame-K seems to have a more pronounced effect to cancel the effect of nicotine of the quasi-crystalline water cluster.

The information derived from the deconvolution of the Raman band of water should be used to explain the results obtained by the physico-chemical methods previously applied [4, 5, and 7]. Again the inhibitors found efficient after interpretation of solution properties, are shown here to exert an antagonist effect to that of nicotine on water structure.

#### 4. CONCLUSION

In order to overcome the problems associated with the unpleasant bitter taste of nicotine used in smoking cessation pharmaceutical formulations (e.g. chewing gums), the solution properties of some artificial sweeteners were studied. Interpretation of results gives an overall picture of the hydrophilicity, hydrophobicity and water mobility of these molecules in aqueous solution. From the results of the present study, we conclude that molecules such as sucrose, Na-gluconate, K-gluconate,  $\beta$ -Cyclodextrin, Aspartame and Acesulfame-K show an antagonist effect on Nicotine. This is derived from the effect of these molecules on the hydrogen bonding of the 4 water species. These results should be completed by sensory evaluations studies.

#### REFERENCES

[1]. Aroulmoji V., Mathlouthi M., Portmann-Richardson MO., 2013. Solution properties and the masking of unpleasant tastes of Nicotine -

Sweetener – Water mixtures. Int J Pharm Sci Res, 4(6); 2190-2198.

- [2]. Aroulmoji V., Mathlouthi M., Portmann-Richardson MO., 2004 (Unpublished Results).
- [3]. Luu, C., Luu, D.V., Rull, Sopron, F., 1982. Raman Effect study of structural perturbation of liquid water by foreign substances. *J. Molecular Structure*, 81, 1-10.
- [4]. Mathlouthi, M., Bressan, C., Portmann, M.O., Serghat, S, 1993. Role of water structure in sweet taste chemoreception. In: Mathlouthi, M., Kanters, J.A & Birch, G.G (eds), *Sweet taste Chemoreception*, Elsevier Science Publishers, London, pp 149-174.
- [5]. Mathlouthi, M., Hutteau, F, 1999. Sweet-bitter interactions and the solution properties of chlorinated sugars. *Food Chemistry*, 37, 95-111.
- [6]. Serghat, S., Mathlouthi, M., Hoopman, T., Birch, G.G, 1992. Solute-solvent interactions and the sweet taste of small carbohydrates. Part I: effect of solvent polarity on solution properties. *Food Chemistry*, 45, 25-32.
- [7]. Aroulmoji, V., Hutteau, F., Mathlouthi, M., Rutledge, DN. 2001. Hydration properties and the role of water in taste modalities of sucrose, caffeine, and sucrose- caffeine mixtures, *Journal of agricultural and food chemistry* 49 (8), 4039-4045
- [8]. Mathlouth, M., Seuvre, A.M., 1988. Solution properties and the sweet taste of small carbohydrates, *J. Chem. SOC., Faraday Trans.1*, 84, 2641-2650.