Food product characterization by acoustical techniques

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Given the fact that food products shall be monitored . . .

- crisp feature
- permeability
- softness
- homogeneity
- presence of inclusions

. . . and may be considered as porous materials

- granular materials
- fibrous materials
- multi-scale porous materials
- effect of porous skeleton

It is not (so) stupid to put food inside an impedance tube!

In fact, earlier works already did: Wilson 2014; Lagrain *et al.* 2006 . . .
Bread : different types

Sound absorption coefficient in impedance tube

White bread

Bread with cereals

Bécot, Gauthier, Chevillotte, Jaouen – fxb@matelys.com : Acoustic food characterisation
Bread: ageing effect on bread properties

Fresh bread

After a few days
Bread: aging effect on bread properties

Characterisation of the parameters which could be linked to the micro-structure

- **acoustic parameters:**
  - open porosity
  - static air flow resistivity
  - viscous and thermal characteristic lengths . . .

- **elastic parameters:**
  - stiffness
  - damping
  - mass density
Micro-structure monitoring while ageing

Open porosity

Static air flow resistivity

ref. Champoux-Stinson-Daigle 1991

ref. ISO 9053
Micro-structure monitoring while ageing

High frequency limit of tortuosity

Viscous characteristic length

ref. Panneton-Olney 2003

⇒ No strong modification of the microstructure arrangement
Micro-structure monitoring while ageing

Thermal characteristic length

Static thermal permeability

ref. Olny-Panneton 2008

⇒ Increase of the pore size
Elastic properties while ageing

Stiffness

Damping loss factor

Mass density

ref. Langlois et al. 2001

⇒ Modifications are tractable regarding the elastic properties as well
Detection of the presence of inclusions

with glass beads

with polystyrene balls
Detection of the presence of inclusions

Parameters examined:
- impervious inclusions
- position
- arrangement
- number
- nature: rigid or elastic
Detection of the presence of inclusions

- detection is possible
- arrangement variations are tractable
- no clear evidence of the elastic effects (for the selected materials)
Breakfast honey corns

- Are the corns porous?
- Is the average size correct?
Modeling approach

- model of porous composite accounting for
  - the shape of the arrangement
  - the porosity of the inclusions

\[ \bar{\rho}_{eq}, \bar{K}_{eq} = \bar{\rho}_{forme_1}, \bar{K}_{forme_2} + \bar{\rho}_{eq_1}, \bar{K}_{eq_1} \]

\[ \bar{\rho}_{forme_2}, \bar{K}_{forme_2} + \bar{\rho}_{eq_2}, \bar{K}_{eq_2} \]

ref. Chevillotte et al. 2012-2014
Sound absorption coefficient

- measured data
Sound absorption coefficient

• porous composite model: mixing law
• porous composite model: impervious spheres
Sound absorption coefficient

- porous composite model: porous spheres
• detection is possible
• porous nature is tractable
  (provided they all are impervious)
• spherical shape is tractable

Sound absorption coefficient

![Graph showing sound absorption coefficient](image)

- Measured data
- Mixing law
- Impervious spheres
- Porous spheres
Cap closing of a yoghurt

- Is the cap closed?
- Is the yoghurt filled?
## Protocol

- measure of sound absorption coefficient in impedance tube
- progressive opening of the cap
Measurement results

![Graph showing sound absorption vs frequency](image)

- YOGHURT
- CAP

*Frequency (Hz) vs Sound Absorption*
Measurement results
Measurement results

![Graph showing sound absorption vs frequency](image)

- Bread
- Rice with inclusions
- Breakfast honey corns
- Yoghurt pot

Conclusion
Measurement results

Sound Absorption vs Frequency (Hz)

Pos. 6
Axi-symmetric finite element

⇒ Default in opening is tractable and even the filling level of the bowl
● Food products may be tested using an impedance tube

● Measured data are relevant for various purposes:
  ○ monitoring of the micro-structure
  ○ control of some inclusions
  ○ quality control of food process
  ○ quality control of packaging

● Further work is ongoing for
  ↦ various (acoustic) control conditions
  ↦ signal processing techniques
  ↦ other products: liquids, functionally graded materials, elastic inclusions

Thank you for your attention and *bon appétit*!