Opportunities in encapsulation for extending the shelf-life of oxidizable food ingredients

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Oxidizable ingredients

- For example:
  - Lipids (vegetable, fish or algal oils)
  - Flavorings – especially those containing citrus oils
  - Natural colorants – paprika, carotenoids, etc.
  - Fat soluble vitamins

Approaches

- Antioxidants – natural or synthetic
- Inert gas packaging (and/or oxygen scavenging)
- Encapsulation

Encapsulation processes

- Coaxial extrusion (e.g. Alginates)
- Granulation
- Extrusion
- **Spray drying** – Assume you know the process
  - Different types of atomization, dryer configurations, stages, sizes, shapes, etc.

Encapsulation presentation

- General introduction to the work done related to oxidation
- Recent work on the encapsulation of edible oils and flavorings (emphasis)
- Opportunities

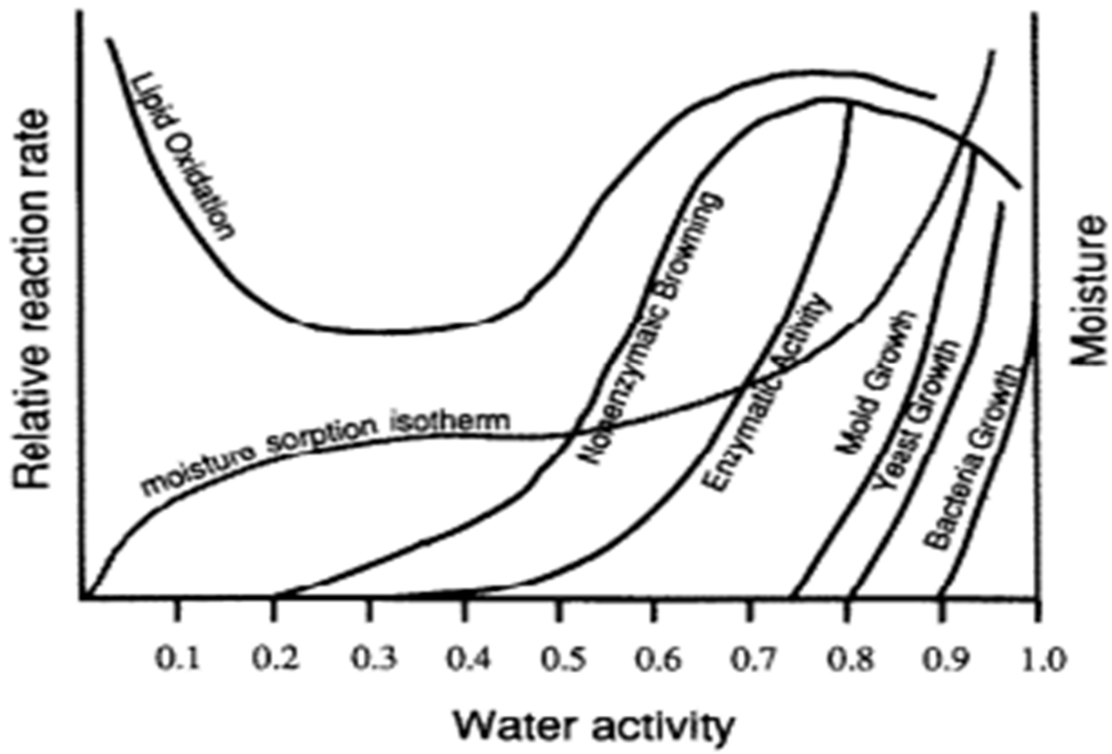
Oxidation of encapsulated - edible oils vs. flavorings

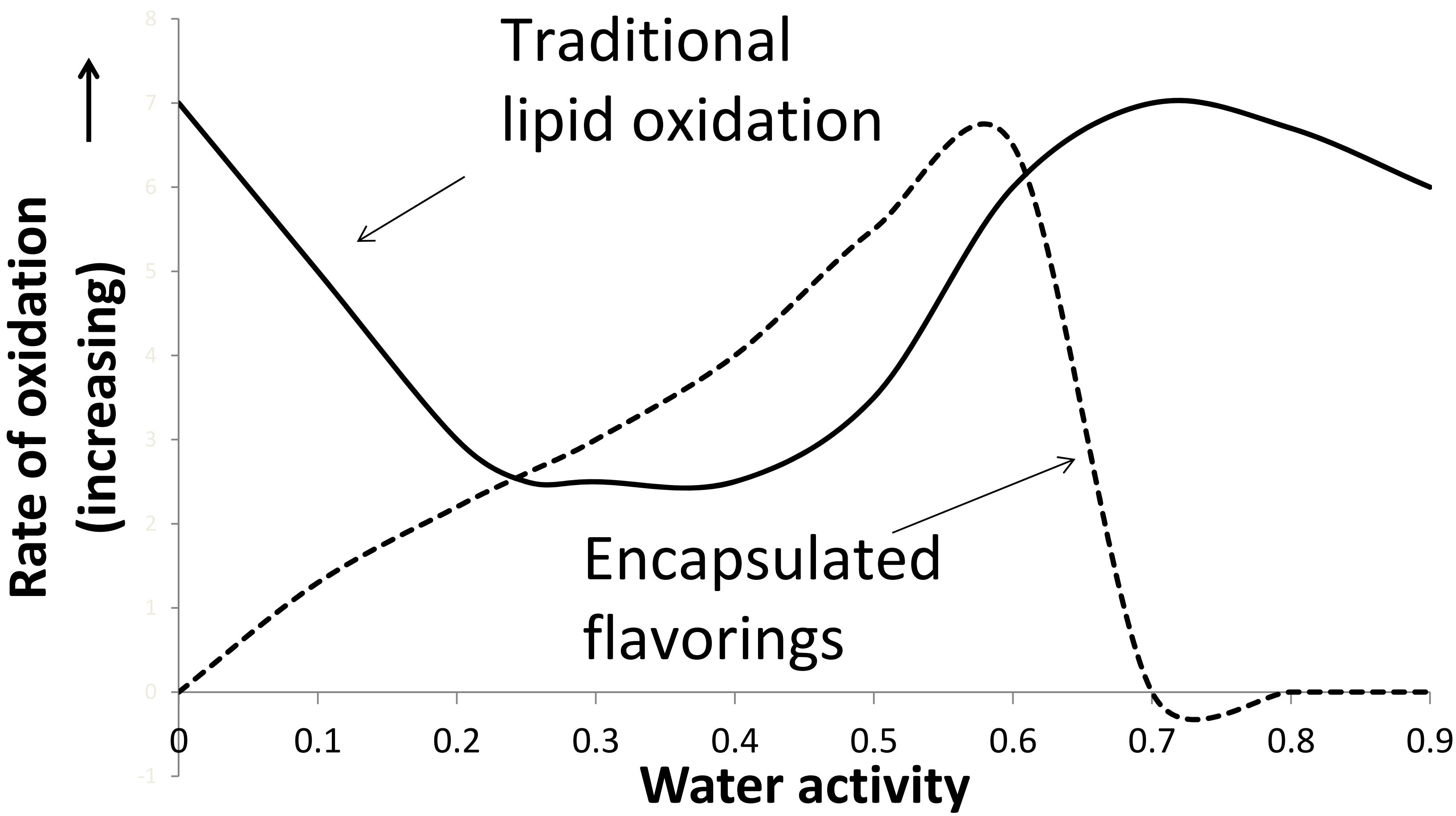
- Edible oils - Concerned with both surface oil AND capsule permeability by oxygen.
- Flavorings – mainly concerned with capsule permeability by oxygen
- Different but similar – use learning across platforms
- Authored a review on this topic – under review

Encapsulated systems do not follow same rules as we observe in food systems.

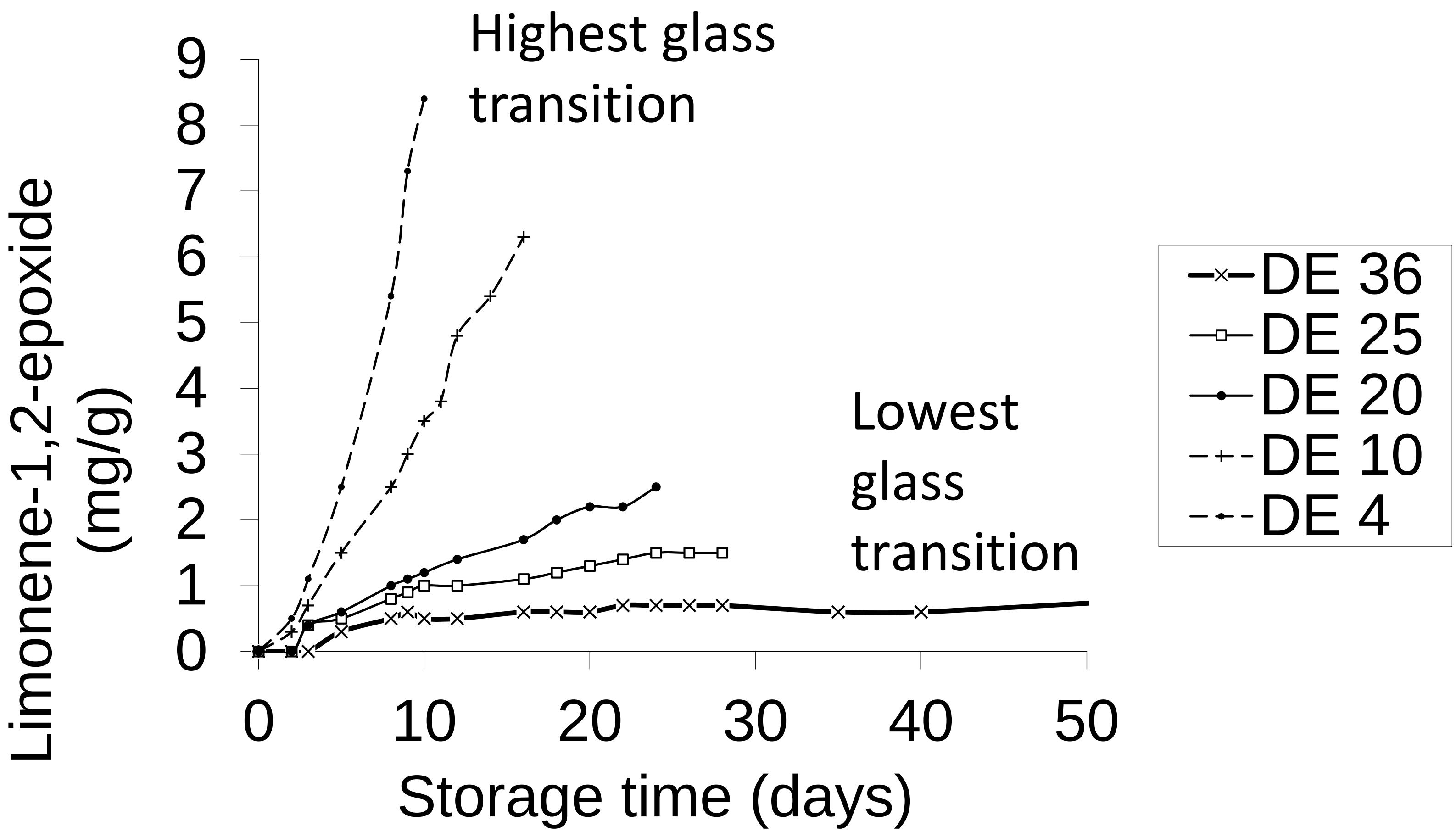
Water activity has strong influence on chemical reactions in foods

- Typical plot




Traditional lipid oxidation
Encapsulated flavorings
Rate of oxidation (increasing)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
Water activity

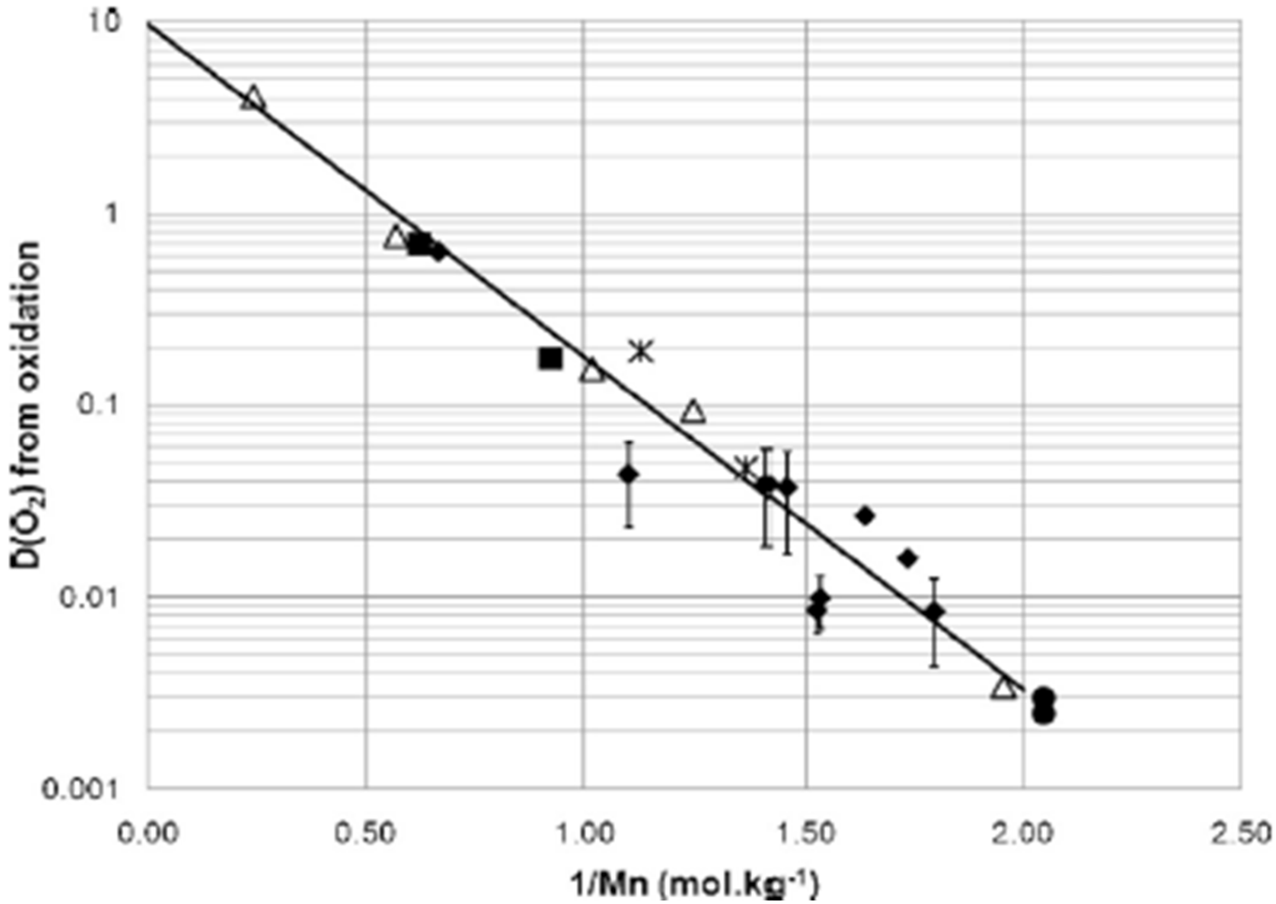
Glass transition?



What have we learned largely through observation?

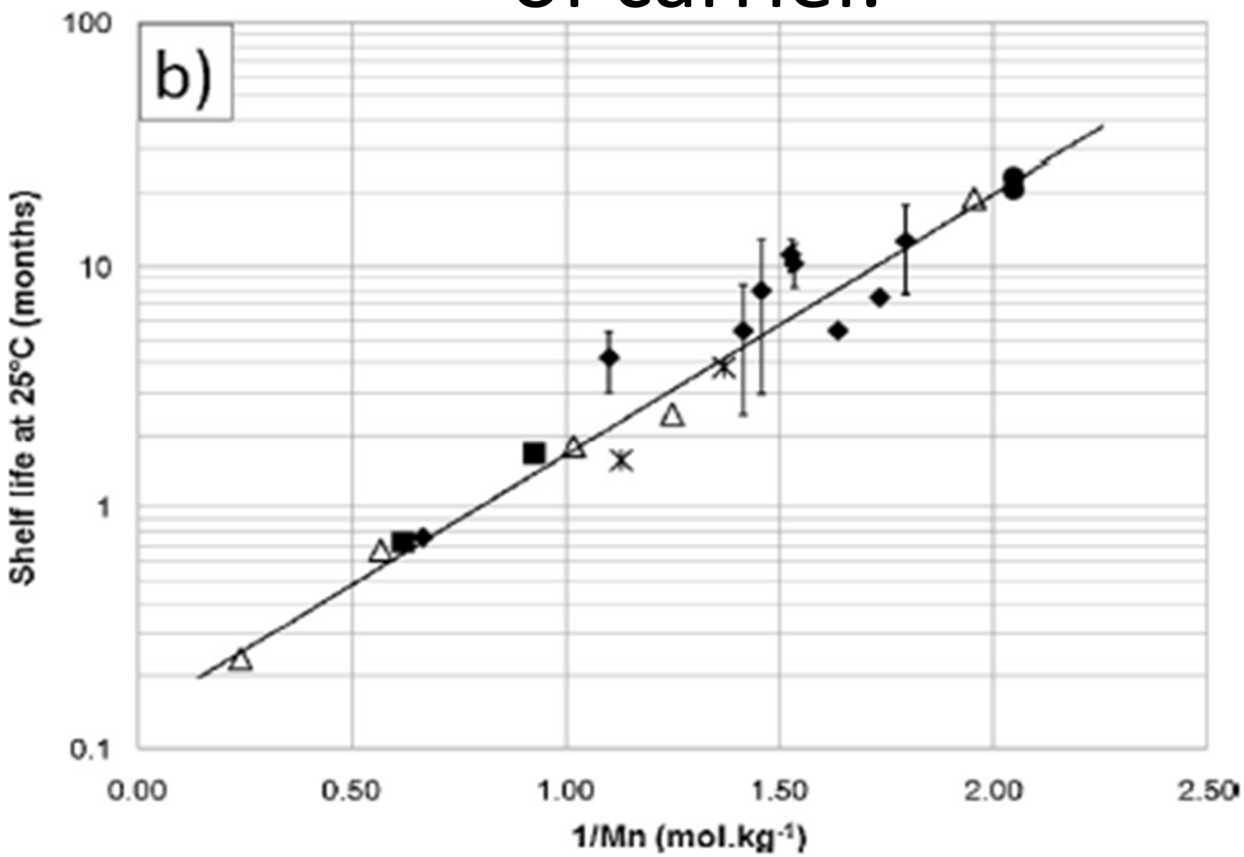
- Dryer operating variables are of little importance (normal operating conditions)
  - Air temperatures, means of atomization, dryer configuration, etc.

- Infeed emulsion is **THE** key variable
  - Type of materials used – low mwt
  - Homogenization – good emulsion



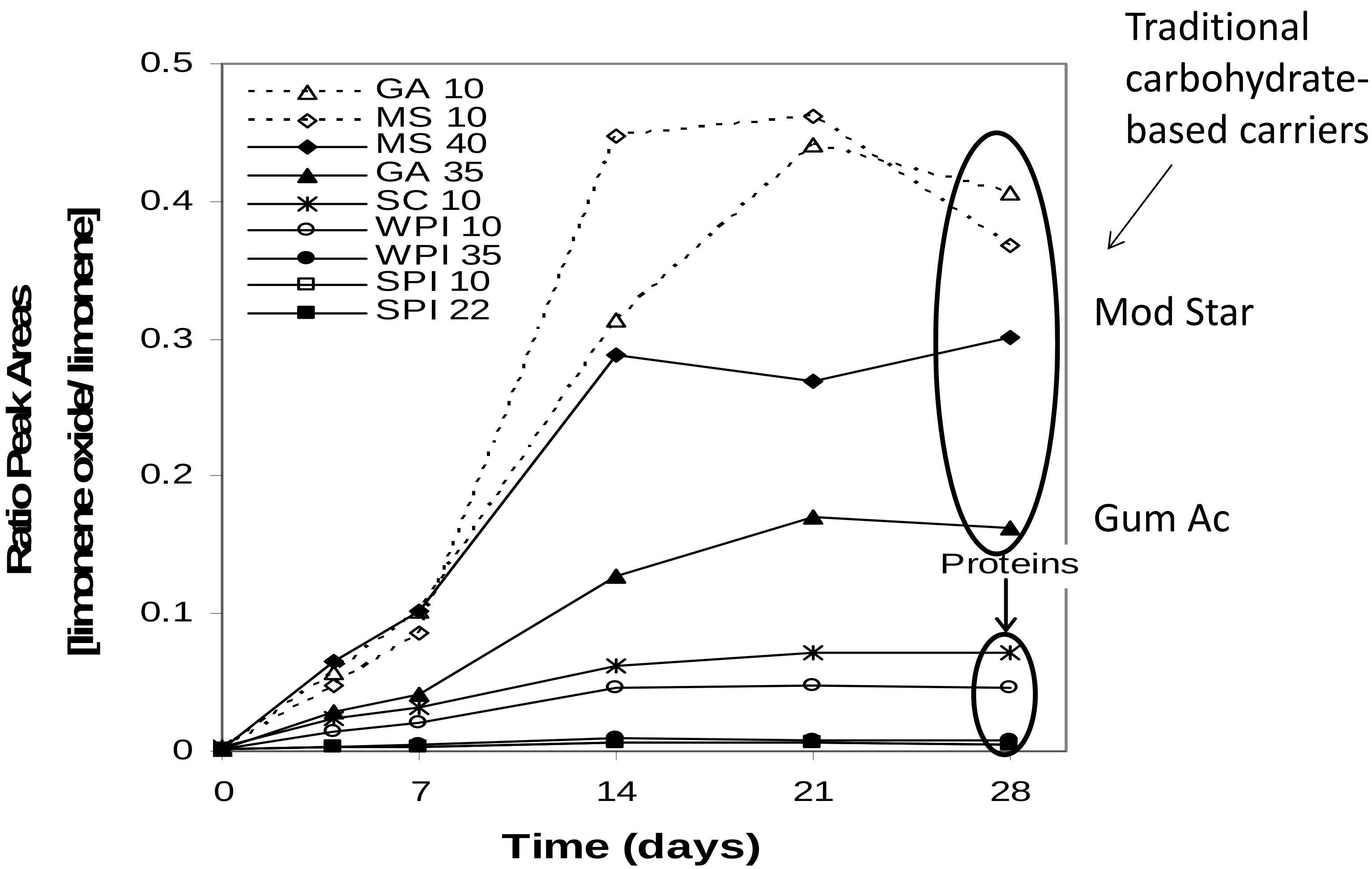
Effect of avg. mol. Wt. of carrier blend on O2 diffusion rate.
(Balance between caking and limiting diffusion)

Shelf – life is a function of molecular weight of carrier.

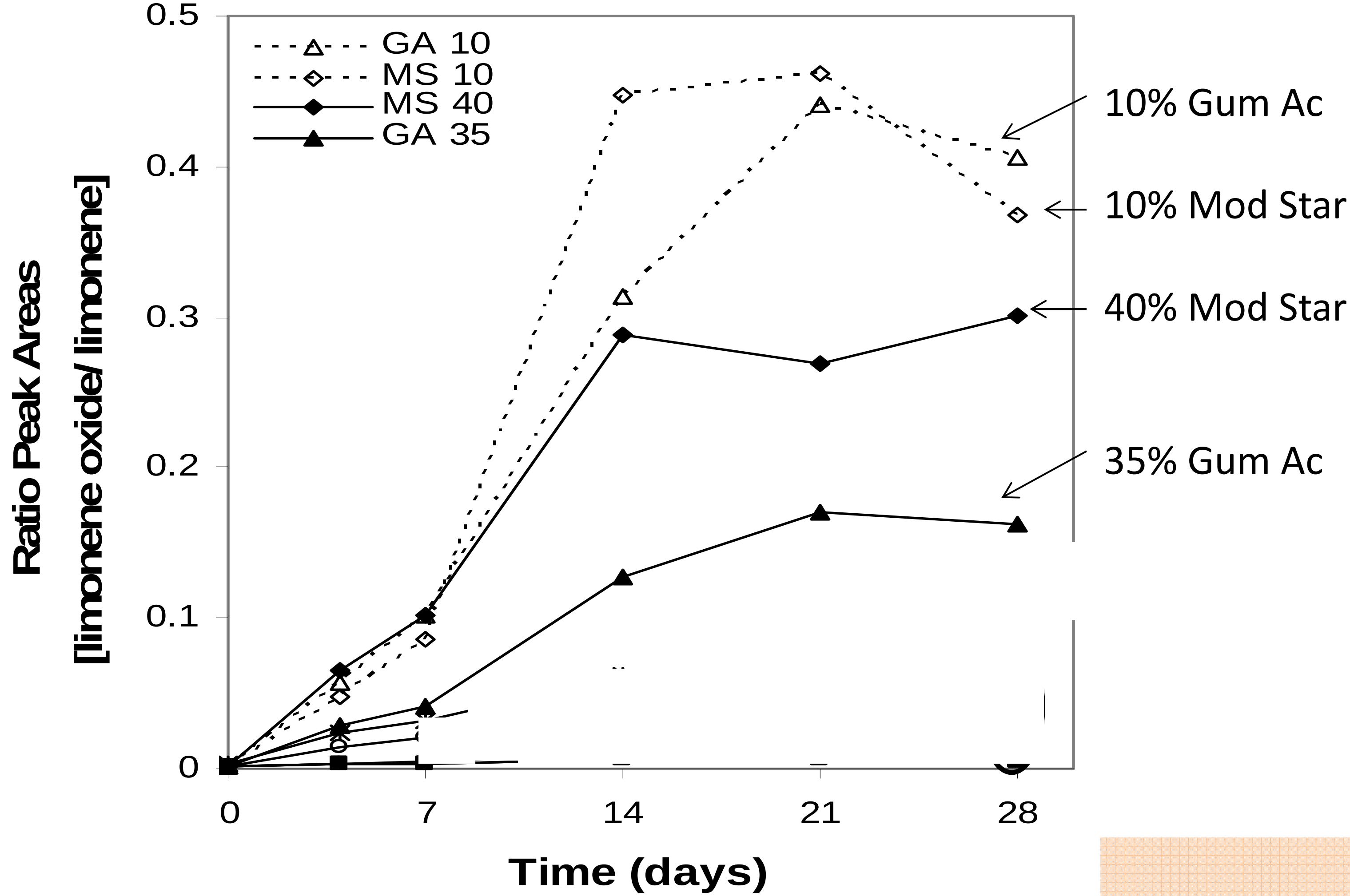


A. Subramaniam, R.L. Veazey, A. Schober, A.Rada,Y Rong, RMT. van Sleeuwen, R.Golding, S. Zhang, V. Normand. Orange oil stability in spray dry delivery systems. Carbohydrate Poly. 97 (2013) 352– 357

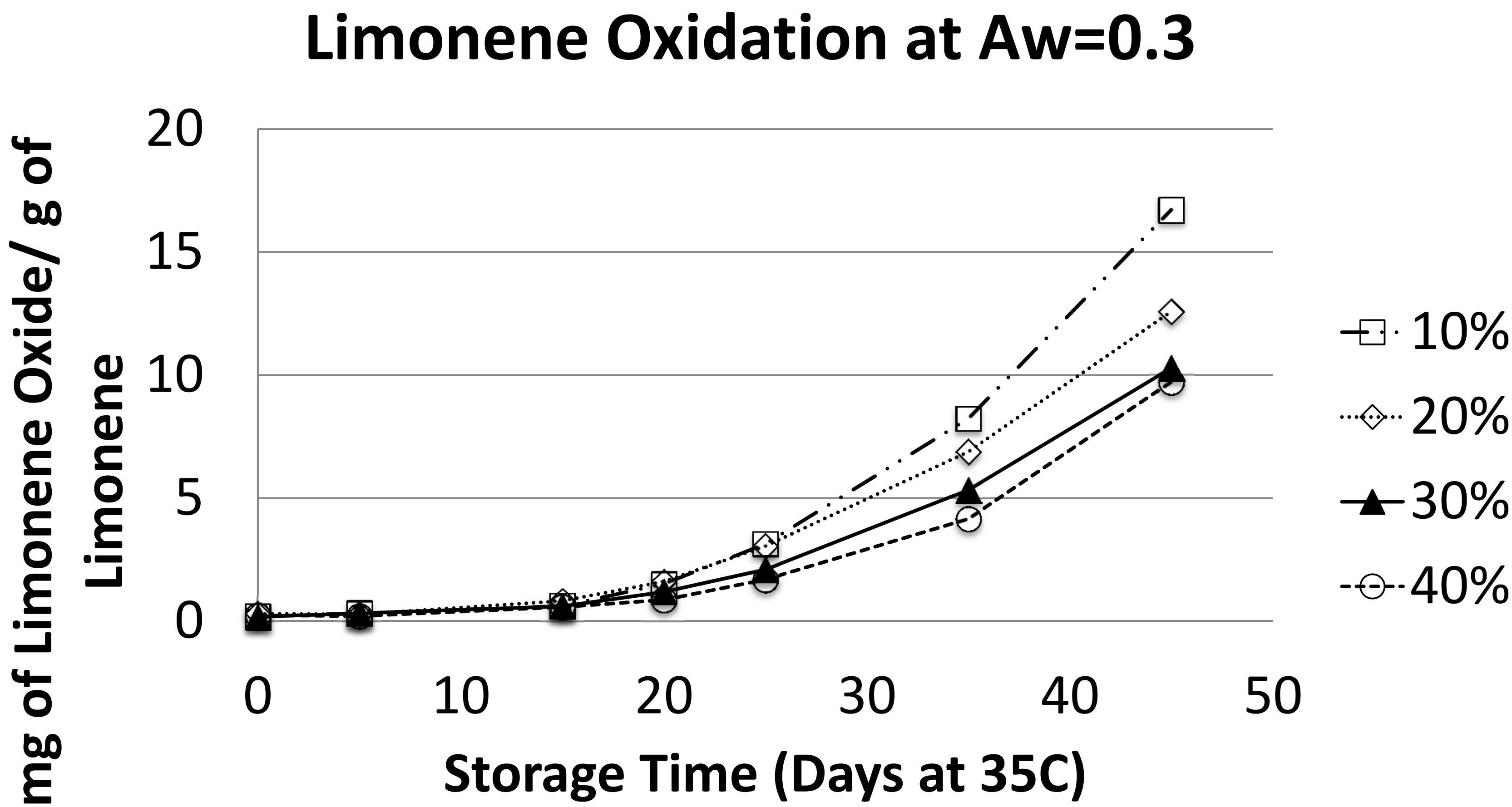
Serendipity (?)



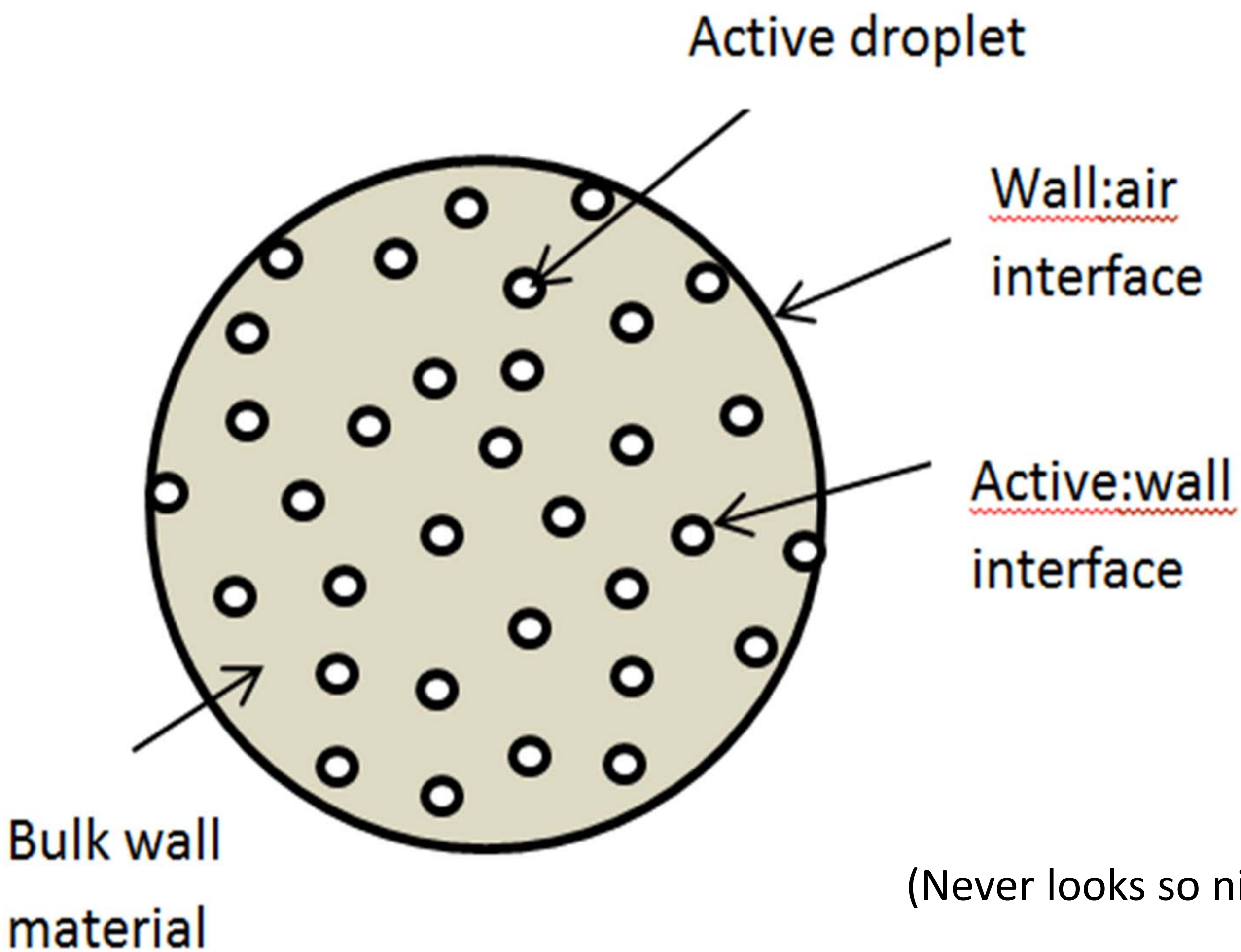
But these are the same formulations and yet different results



Gum acacia – 15 DE Maltodextrin (1:1)



Barriers to oxygen migration



(Never looks so nice)

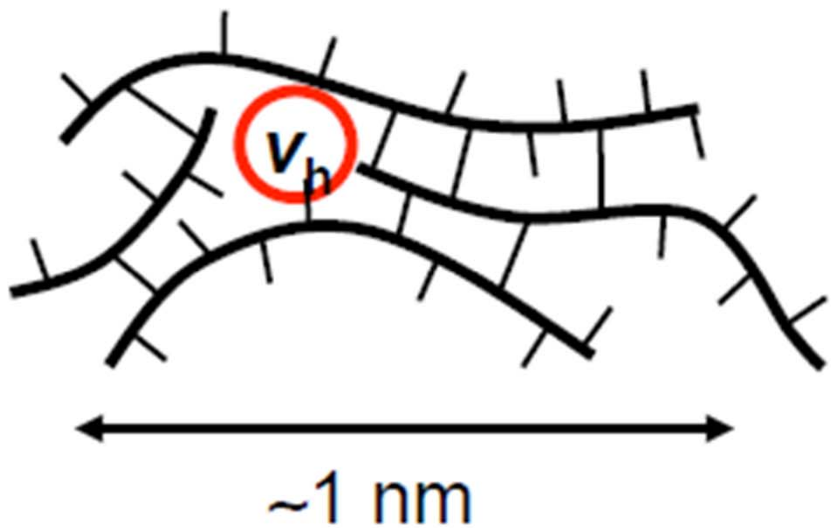
Diffusion in amorphous systems – Fickian

- Depends upon there being pores (voids) in material (places large enough for oxygen to "slip" into – number and size are important)

- Some flexibility (mobility) of the matrix – polymers move which allows movement of oxygen

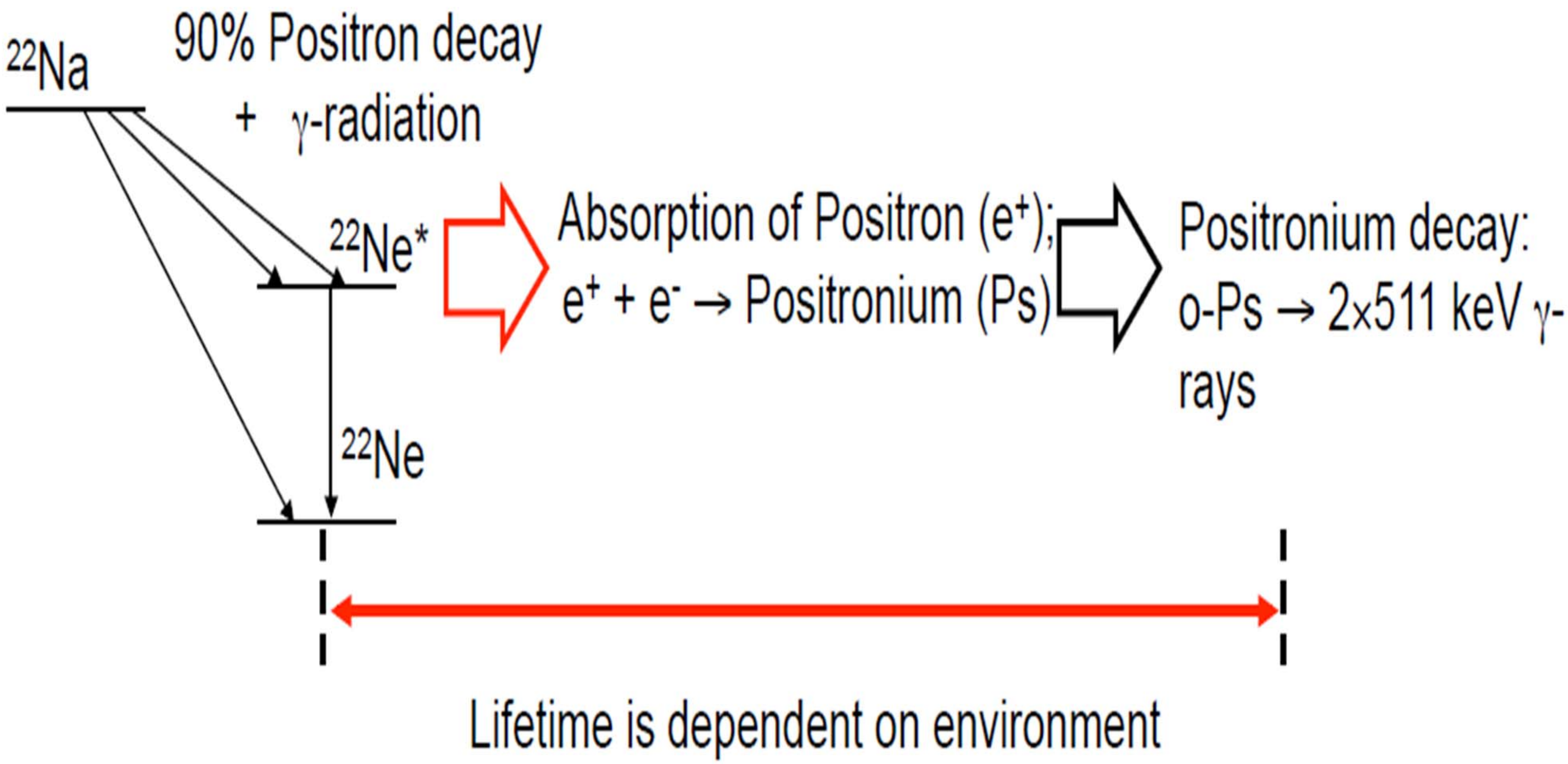
Pores in polymer matrix – dimensions accommodate Oxygen

$$V_h = \frac{4}{3}\pi r^3$$



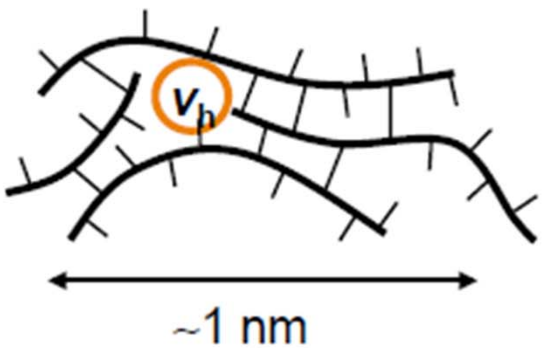
Positron Annihilation Lifetime Spectroscopy (PALS)

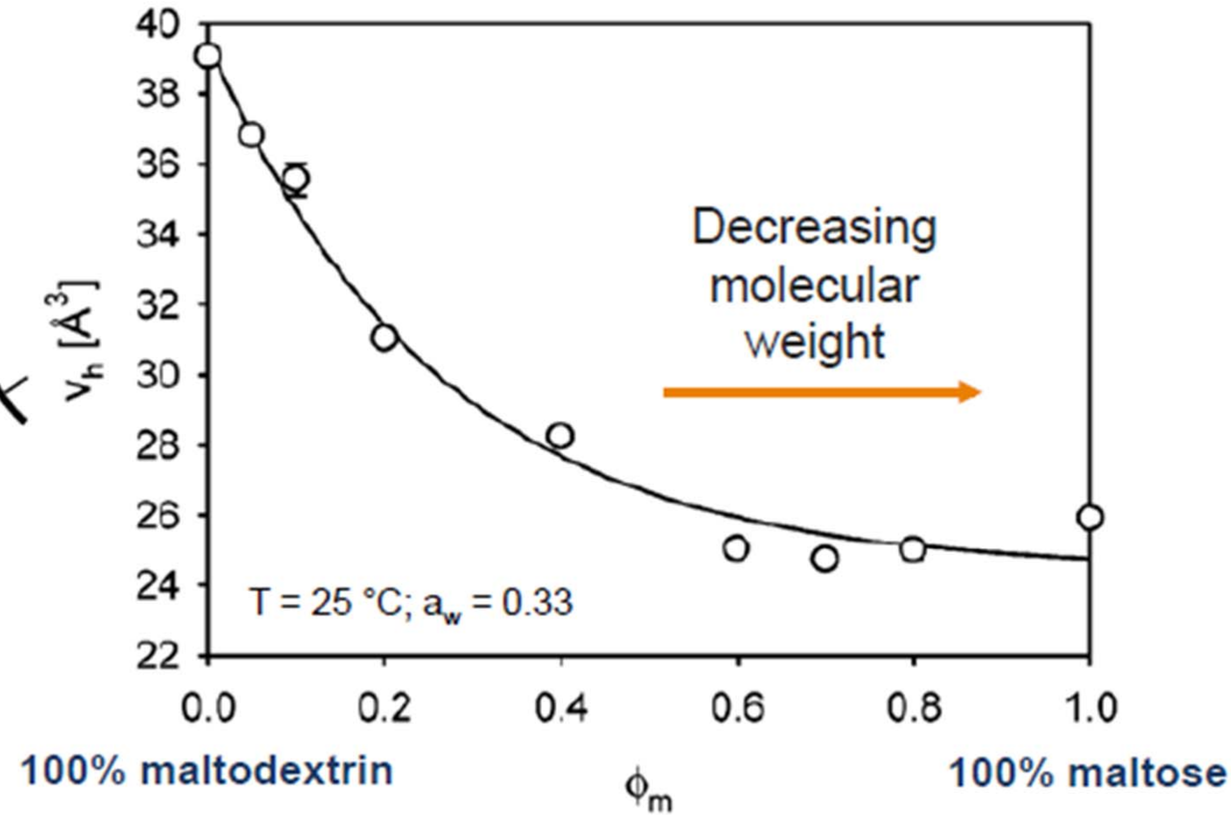
PALS



Job Ubbink, The Mill

- Hole volume vh and specific volume Vsp decrease with decreasing Mw below Tg





Job Ubbink, The Mill

Oxidation rate increases with water activity

- Hole size expansion by water at slightly higher water contents

- Molecular mobility – increased with water activity (have tools to measure this property)

Formulation - Bottom line

- We have tools to optimize the carrier system for oxygen barrier properties!
- Data suggest that the challenge (opportunity) is to create the lowest avg mwt matrix that does not cake (collapse)
- Back to that later

Can we tailor the particle surface to be less "sticky"

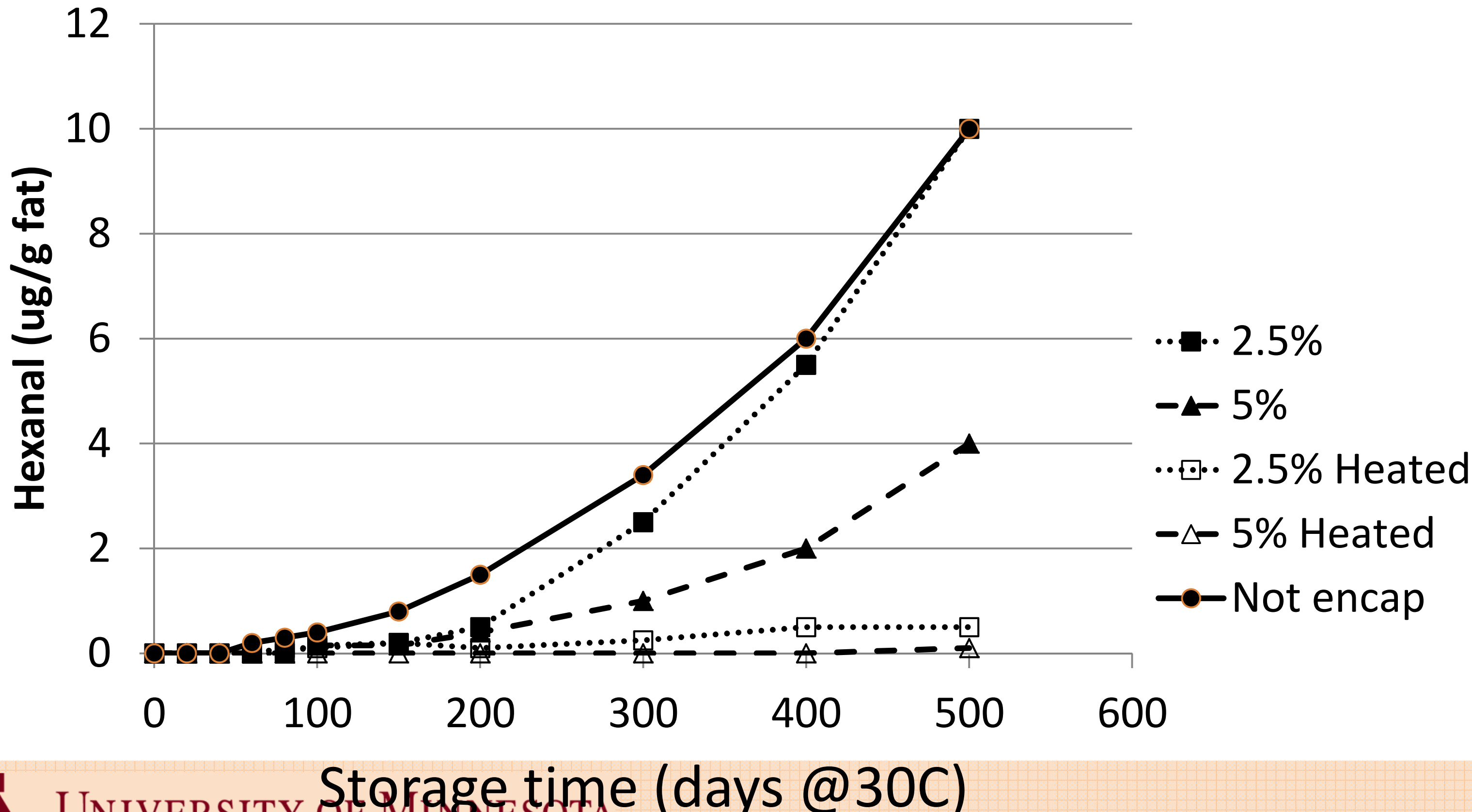
- Particle surface: air interface (0.1 – 1 msec opportunity to migrate)
  - Skimmilk powder
    - Bulk composition - 58% lactose, 41% protein and 1% fat
    - Surface - 36% lactose, 46% protein and 18% fat.
  - Whole milk powder
    - Bulk composition 40% lactose, 31% protein and 29% fat,
    - Surface - 2% lactose, negligible amount of protein and 98% fat.

Can we tailor the system to change the oil:wall interface?

- I believe this is what we did when we changed the infeed solids – drove some components to the interface.

Small amounts of proteins can be effective at providing an oxygen barrier

- 2.5 or 5% Whey Protein Isolate + 40% butterfat + Maltodextrin or NFDM (Data from Rosenberg)



Can we formulate to create an oxygen impermeable droplet interface?

- Proteins without allergenic properties (pea)
- Glycosylated proteins
- Hydrolyzed/glycated proteins?
- Any surface active components (weighing agents?)
- Multi layer emulsions – Stephan Drusch (U Berlin)

Plasticization of the interfaces

- Water and glycerol – have data
- What about other polar flavor molecules?
  - Will a formulated orange flavoring be less stable than an essential oil? (small mwt, fresh, aroma compounds)
  - Flavor solvents

Future

- Focus on the flavor droplet:wall interface
  - Very low levels of ingredient – large opportunity
- Opportunities to influence surface composition
  - Limited opportunity ?
- Optimize process and formulation
  - New materials
  - Optimum blends of existing materials
  - Unique fractions of existing materials – gum acacia, other gums?