Changes in water state and distribution in soy containing bread during storage

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Abstract

SOY contains high quality protein associated with reduced risk of coronary heart disease. Addition of large quantity of soy to bread formula has been difficult because of lower sensorial acceptability of soy containing bread. Understanding the state and distribution of water in soy bread and its evolution during storage may lead to an optimized bread formulation with an acceptable shelf-life.

The objective of this study was to measure the changes in the state of water over time in both soy bread crumb and crust.

An acceptable bread containing 30% soy was produced and stored in polyethylene bag at room temperature for up to 14 days. The state of water in crumb and crust of bread was analyzed by thermal analysis (DMA, DSC, TGA) and by ^{1}H NMR (T_1 and T_2 relaxation times).

The total moisture content decreased from 44.7% to 42.0% in bread crumb and increased from 23.4% to 35.3% in soy bread crust over 14 days of storage. The "freezable" water content in both crumb and crust increased over time but in different amounts (5.7% and 8.7%, respectively). The "unfreezable" water content decreased by 8.4% in bread crumb but increased by 3.2% in bread crust during storage. DMA results of bread crumb showed no change in the transition at 0°C with increased storage time. No significant change was found in ^{1}H T_1 and T_2 in both crumb (236 and 8.5ms) and crust (218 and 8.3ms) indicated stability in ^{1}H averaged mobility during storage.

Water redistribution between soy bread crumb and crust is an indication of product instability and needs to be controlled to maintain the freshness of bread. Future studies in chemical additives as well as effective packaging are needed to ensure appropriate shelf-life of the soy bread.

Background

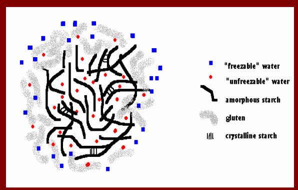


Figure 1. Bread - an heterogeneous system

Baked bread

- a heterogeneous system
- subjected to physicochemical instability during storage
- **water** plays a critical role in determining the quality and stability of bread through
  - Moisture redistribution
  - Moisture loss
  - State of water

during storage.

Objective

To measure the changes in the state of water over time in both soy bread crumb and crust

Experimental plan

Physico-chemical Property Study (DMA/DSC/TGA)

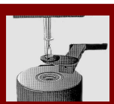
Molecular Mobility Study (NMR)

Fresh Soy Breads → **Storage Study** → **Stale Soy Breads**

- Fresh soy bread ("30% soy on t.b.") / Fresh wheat bread (control)
- Cooled for 40 min at room temperature
- Packed in polyethylene bag
- Stored with crust at room temperature for 14 days
- On day 0 (fresh), 1, 2, 4, 7, and 14 soy bread crumb and crust were separated for analysis

Methods

Thermogravimetric Analyzer (TGA) (TA Instrument, TGA2950)
- Sample size: 15-20mg
- Temp range: 25-180°C
- Heat rate: 20°C/min



Differential Scanning Calorimetry (DSC) (TA Instrument, DSC2920)
- Heating Rate: 5 °C/min
- Temp Range: -50 °C – 150 °C
- Sample Size: 8 - 10 mg

Dual cantilever clamp for bending mode test

Dynamic Mechanical Analyzer (DMA) (TA Instrument, DMA2980)
- Heat Rate: 2°C/min
- Temp Range: -80 °C – 110°C
- E' curve fit with modified Fermi equation (Peleg, 1994)

Nuclear Molecular Resonance (NMR)(300MHZ, Bruker)
- ^{1}H T_1 (spin-lattice relaxation time)
- ^{1}H T_2 (spin-spin relaxation time)

Results

TGA

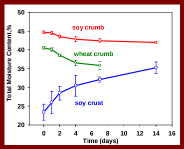


Figure 2. Changes in moisture content during storage by TGA.

The total moisture content decreased from 44.7% to 42.0% in soy bread crumb and increased from 23.4% to 35.3% in soy bread crust over 14- day storage. The total moisture content decrease from 40.5% to 35.9% over 7-day storage in wheat bread crumb.

DSC

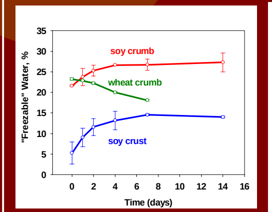


Figure 3. Changes in "freezable water" during storage.

The "freezable" water in both soy bread crumb and crust increased over 14-day storage (+5.7% and +8.7%, respectively). The "freezable" water in wheat bread crumb decreased over 7-day storage (-5.1%)

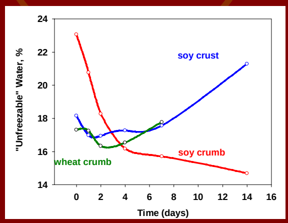


Figure 4. Changes in "unfreezable" waterduring storage (calculated).

The "unfreezable" water in soy bread crumb decreased (-8.4%) but increased in soy bread crust (+3.2%) over 14-day storage. The "unfreezable" water in wheat bread crumb did not change over 7-day storage.

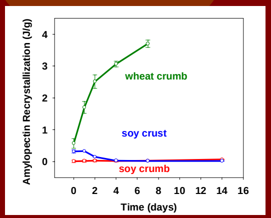


Figure 5. Changes in recrystallization of amylopectin during storage.

The amount of crystallized amylopectin in soy bread did not change over 14-day storage, however increased over 5 times in wheat bread crumb over 7-day storage (Vittadini and Vodovotz, 2003).

DMA

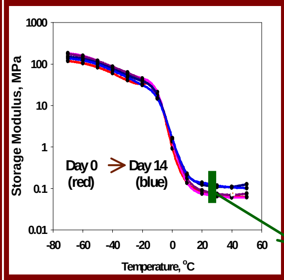


Figure 6. Changes in storage modulus (E') of soy bread during storage.

Modified Fermi equation results showed no change in storage of the E'(T) with the slope ranging from 12-13 and the Midpoint temperature ~ -38 °C.

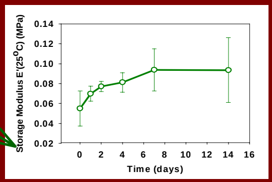


Figure 7. Storage modulus at 25 °C increased slightly with storage time indicating an increase in stiffness.

NMR

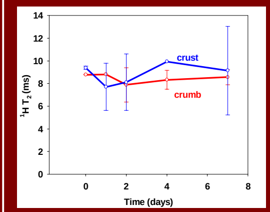


Figure 8. Changes in ^{1}H T_2 (spin-spin relaxation time) in soy bread during storage.

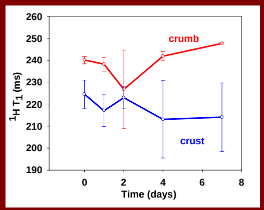


Figure 9. Changes in ^{1}H T_1 (spin-lattice relaxation time) in soy bread during storage.

Neither T1 or T2 of soy bread crumb or crust changed during storage indicating little change in the proton mobility during storage unlike wheat bread (Chen et al., 1997). The T_1 and T_2 values measured were the weighted average of the contribution of all the multiple ^{1}H populations present in soy bread. These relaxation times were not only attributed to water but also include contributions of protons on other polymers/solutes.

Conclusions

SOY:

- ✓ Increases fresh crumb moisture content
- ✓ Decreases the rate of moisture loss in bread during storage
- ✓ Changes the redistribution of moisture in bread during storage
  - "freezable" water in soy crumb increases vs. decreases in wheat crumb
  - "unfreezable" water in soy crumb decreases and in soy crust increases vs. unchanged in wheat bread crumb

Both proton mobility and storage modulus of soy bread were unchanged during storage.

References

Peleg, M. **Mathematical characterization and graphical presentation of the Stiffness-temperature-moisture relationship in gliadin.** *Biotechnology Progress*, 1994 (*10*) 652-654

Chen, P. L.; Long, Z.; Ruan, R. **Nuclear magnetic resonance studies of water mobility in bread during storage**. *Lebensm-Wiss. u. Technol.* 1997(*30*) 178-183

Vittadini, E. and Vodovotz. Y. **Comparison of physico-chemical properties of wheat and soy containing breads during storage as studied by thermal analysis**. *Journal of Food Science* (will be published in August 2003).