Exploration of functionality of low-glycemic-impact sugars and polyols, using SRC, DSC, RVA, and cookie baking

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Background

- Sugar functionality in cookie baking varies, depending on sugar type and extent of dissolution during mixing and baking.

- Anti-plasticizing action of high sucrose concentration in a cookie formula inhibits both gluten development during mixing and starch gelatinization/pasting during baking, resulting in loss or absence of readily digestible starch.

- If alternative sugars and polyols with low glycemic impact are used to replace sucrose, the combination of sucrose replacement and absence of readily digestible starch allows production of healthier cookies.

- For successful sucrose replacement, cookie-baking behavior must be linked to flour functionality.

Effect of gluten development on cookie baking

(Time-lapse photography)

Bad for cookies:

Retention of height =

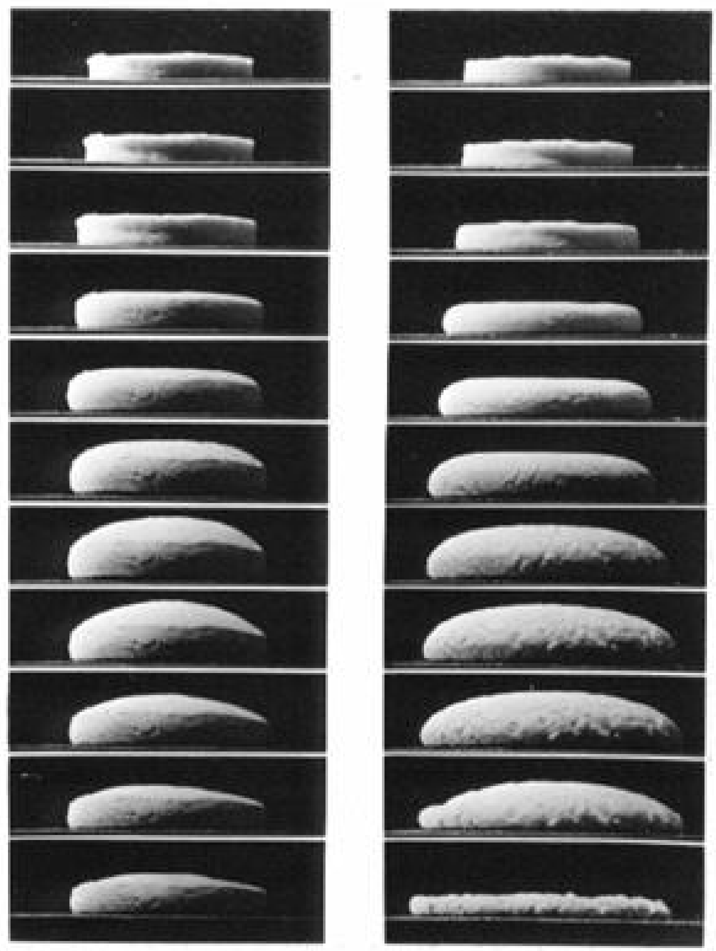
elastic recovery =

presence of networks due to excessive glutenin development during mixing

Baking Time

Bread flour | SRW flour

0
1
2
3
4
5
6
7
8
9
10
(min)



(Yamazaki and Lord, 1978)

Good for cookies:

Loss of height =

failure by collapse =

absence of networks

How to describe the functionality of sugar and water together

TS = **Total Solvent => Controls CREEP**
= Total Syrup = Sum of Sugars + Water

% S = **Sugar Concentration => Controls COLLAPSE**
= Concentration of Syrup Made by Sugars + Water
= Sugars / (Sum of Sugars + Water)
= Sugars/TS

Effect of TS and %S on cookie baking

Experimental design range of TS and %S: ~ AACC 10-53 Wire-Cut to ~ 10-50D Sugar-Snap

TS	**63**	**63**	**83**	**83**
%S	**63.5%**	**72.3%**	**63.5%**	**72.3%**

Effect of extent of dissolution of sugar during mixing (due to particle size)

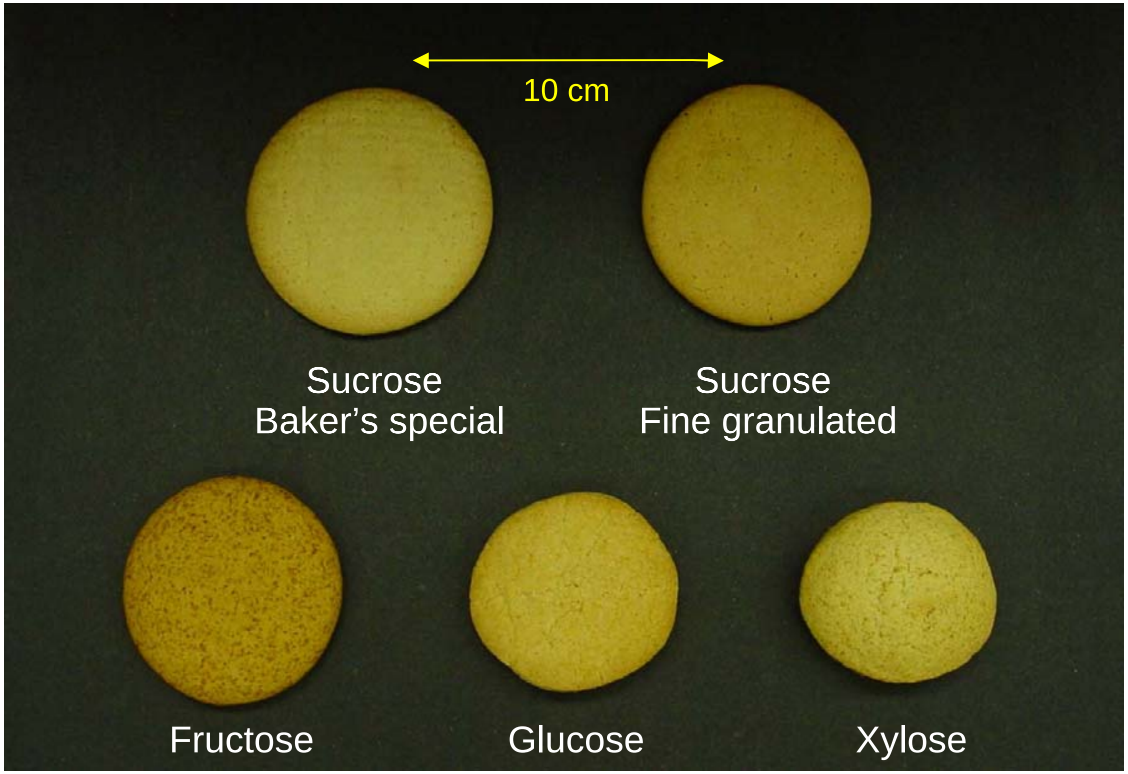
(AACC 10-50D sugar-snap cookie baking)

Medium Extra fine Baker's special

Effect of sugar type on cookie baking

(AACC 10-53 wire-cut cookie baking)

Top view



Side view

Objective

Explore the effects of sugar-replacer type (sucrose, potential sucrose-replacing sugars and polyols) on SRC, DSC, RVA, and cookie baking.

Materials

- **Flour (milled Croplan 594W, SRW)**

  - Straight-grade flour (74% milling yield).

pH	Moisture Content (%)	Solvent Retention Capacity (%)			
		Water	Lactic acid	$NaCO_3$	Sucrose
5.9	13.3	47.8	82.9	64.5	83.4

- **Sugars and polyols**

  - Ribose, tagatose, sucrose
  - Xylitol, maltitol, lactitol, polydextrose

- **Shortening**

  - Zero-trans-fat Crisco® shortening

Glycemic response of sugars

Sugar type	Glycemic response (g GGE/100g)
Ribose*	≈0
Tagatose	3
Xylitol	12
Sucrose	68
Maltitol	45
Lactitol	5
Polydextrose	≈5

(* Segal et al, 1957; Livesey, 2006)

Methods

- **Differential Scanning Calorimetry (DSC)**

  - DSC model : DSC 7 (Perkin Elmer, CT, USA)
    - Heating rate : $10^{o}C/min$
    - Heating range: 30 – $130^{o}C$
    - Reference pan: empty pan

- **Rapid Visco-Analyzer (RVA)**

  - Model: RVA-4 (Newport Scientific, Australia)
    - Sample concentration: 3.5g (db) flour + 25mL solvent
    - Heating rate: $5^{o}C/min$
    - Temperature range: $50^{o}C \rightarrow 95^{o}C \rightarrow 50^{o}C$

- **Solvent Retention Capacity (SRC)**

  - AACC 56-11 Method, 50% w/w sugar solutions

- **Cookie Baking**

  - AACC 10-53 Wire-Cut Cookie Method

Ingredients and formula for cookie baking

(AACC 10-53 Wire-cut cookie method)

	Weight (g)
Flour	225[1]
Sucrose	94.5
Nonfat dry milk	2.3
NaCl	2.8
Ammonium bicarbonate	1.1
Sodium bicarbonate	2.3
Shortening	90.0
High fructose corn syrup	3.4
Added water	49.5
Calculated TS[2]	64
Calculated % S[3]	66

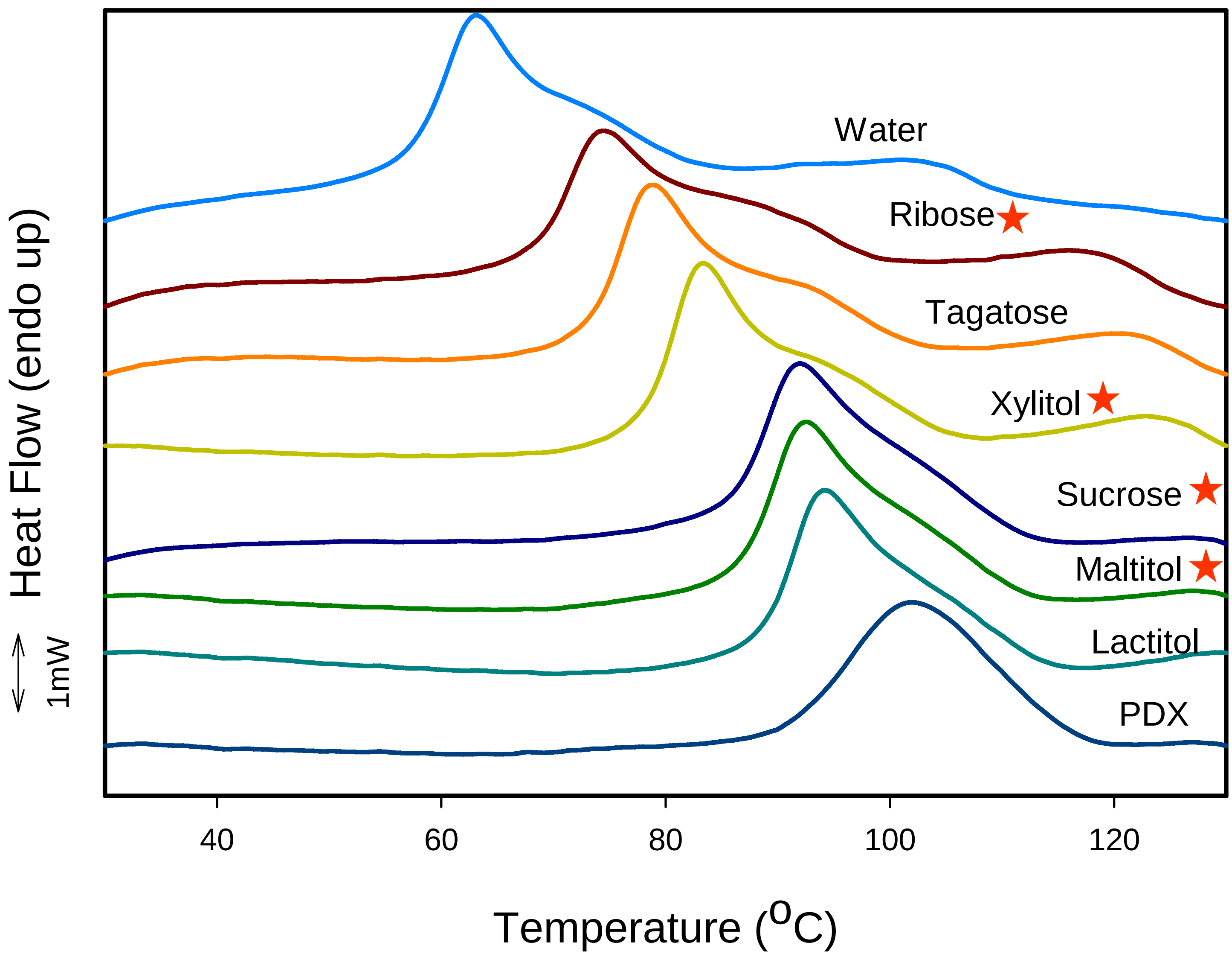
[1] Method 10-53 assumes 13% flour water content.

[2] Total Solvent (TS) calculated as the sum of sugar weight and the total formula water weight, based on 100g of flour.

[3] S% calculated as sugar weight divided by the total solvent weight, based on 100g of flour.

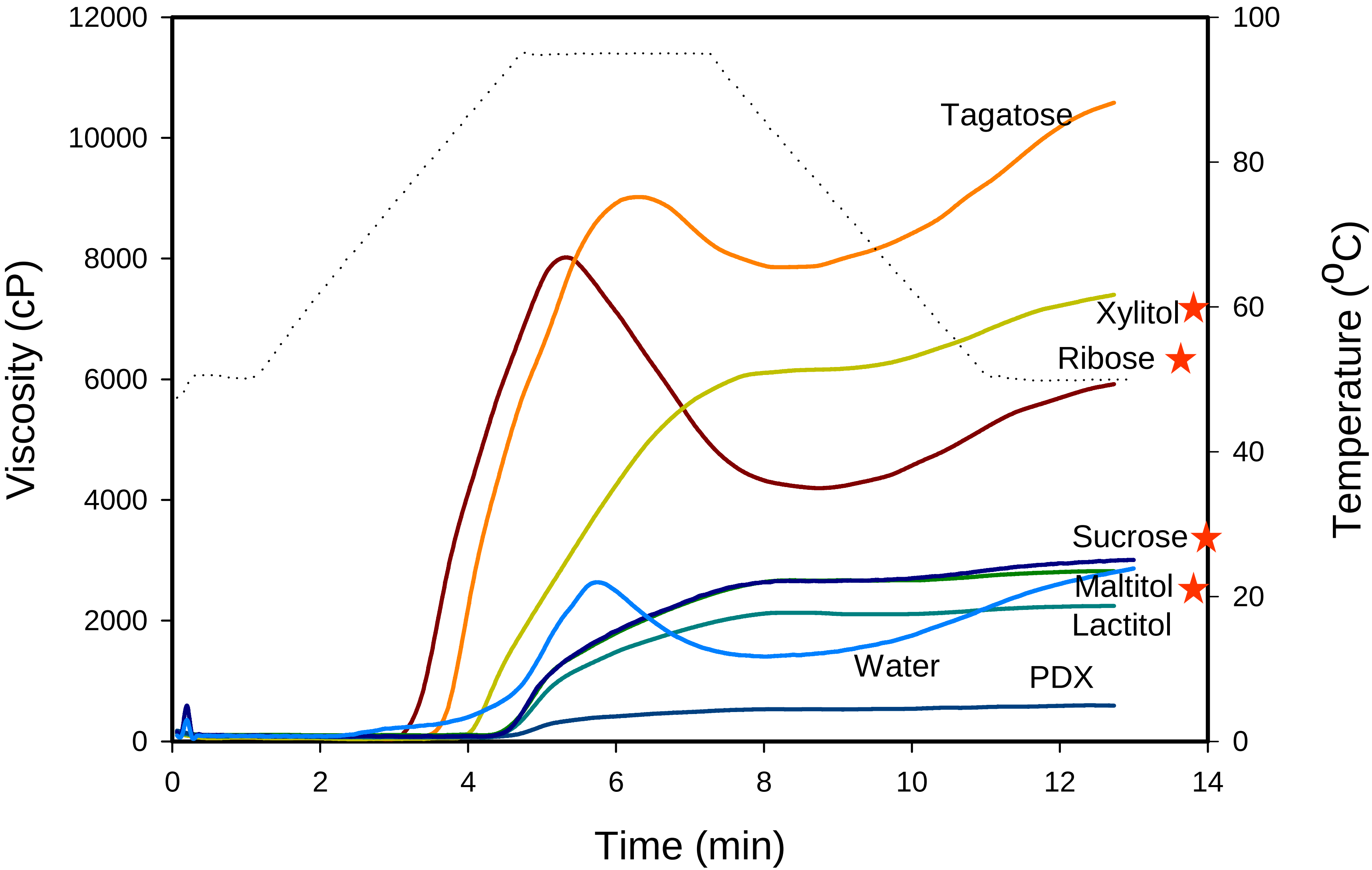
DSC of flour in 50% sugars and polyols

★ Selected for time-lapse photographs during cookie baking



RVA of flour in 50% sugars and polyols

★ Selected for time-lapse photographs during cookie baking



Characterization of sugars and sugar alcohols

Sugar	Solubility (w%, 25^oC)	Dry Tg[1] (^oC)	SRC[2] (%)
Xylitol	64	-18.5	73
Lactitol	64	nd	74
Maltitol	61	44	76
Sucrose	67	52	83
Glucose[3]	51	31	82
Polydextrose	80	110	83
Fructose[3]	80	11 & 100	85
Tagatose	57	40.5	86
Xylose[3]	56	9.5	91
Ribose	>>80[4]	-10	99

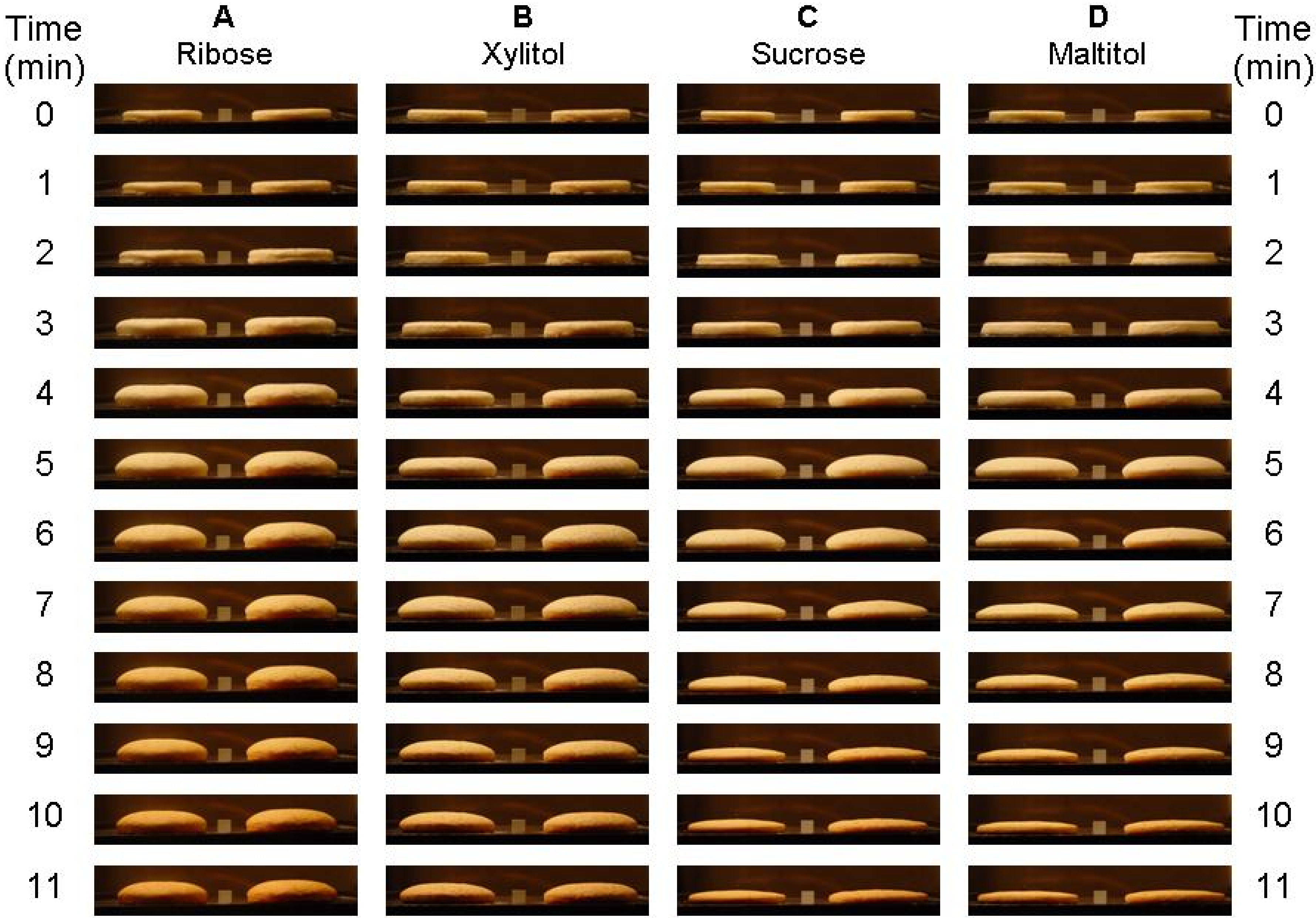
[1] Dry glass transition temperature (Tg) values from Slade and Levine (1991).
[2] SRC % for Croplan 594W flour in 50% w/w solution.
[3] Glucose, fructose and xylose were used previously for cookie baking, as reported in Kweon et al. (2009)
[4] Unlike fructose, which can be crystallized by seeding from its saturated solutions, the water solubility of ribose is so much greater that it cannot be crystallized, even by seeding (Angyal 2005).

Moisture loss, cookie geometry, and color of baked cookies

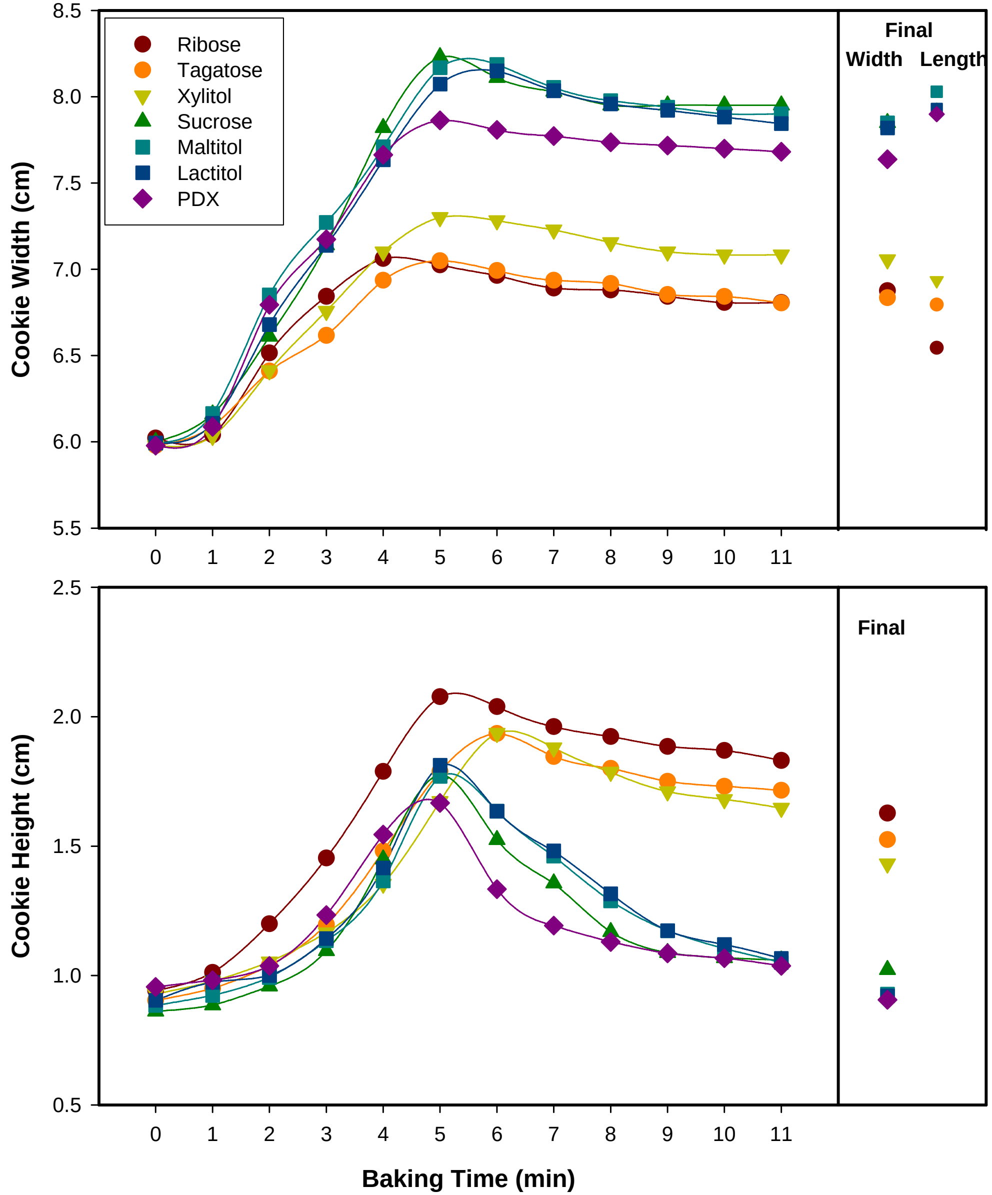
Sugar	Dough Firmness[1] (g force)	Weight Loss (%)	Cookie geometry[2] (1 ps)			Top surface color		
			Width (cm)	Length (cm)	Height (cm)	L*	a*	b*
Ribose	122e[3]	10.55b	6.88b	6.55c	1.63a	63.1d	15.9a	48.1a
Tagatose	202cd	10.14b	6.84b	6.70c	1.53b	62.4e	14.9b	40.2b
Xylitol	217bc	10.29b	7.06b	6.94b	1.43c	74.5b	7.9c	36.2c
Sucrose	169d	13.05a	7.85a	7.92a	1.02d	74.2b	7.4d	33.5e
Maltitol	250ab	13.15a	7.85a	8.03a	0.93e	76.6a	5.8f	34.3d
Lactitol	263a	13.72a	7.82a	7.93a	0.92e	77.0a	4.9g	33.9de
Polydextrose	192cd	13.51a	7.64a	7.90a	0.91e	70.6c	6.9e	31.5f

[1] Dough firmness (average of six measurements, three measurements from each of the duplicate doughs)
[2] Cookie geometry (average of eight pieces, four pieces for each of the duplicate doughs)
[3] Means followed by the same letters within each column are not significantly different at p=0.05, Tukey-Kramer test.

Selected time-lapse photos for cookies



Data analysis from time-lapse photos for all sugars and polyols



Conclusions

- DSC and RVA of wheat flour in 50% sugar solutions showed retardation of starch gelatinization and retardation of the onset of starch pasting, respectively, compared to that in water.
- Cookie-baking results showed that wire-cut cookies formulated with xylitol, tagatose and ribose exhibited snap-back. In contrast, cookies formulated with maltitol, lactitol, and especially polydextrose showed facilitated flow and elongation in the direction of dough sheeting.
- Time-lapse photography during baking demonstrated that maltitol and lactitol cookies exhibited the most similar baking responses to those for sucrose, among all the potential sucrose-replacers. Those two polyols could be used most easily as sucrose substitutes, to produce healthier cookies with lower glycemic impact.
- The cookie-baking behavior for polydextrose was sufficiently similar to that for sucrose, so that a blend of polydextrose with maltitol and/or lactitol could be used to replace sucrose, thus providing the additional benefits of a prebiotic soluble fiber.
- SRC, DSC, RVA, and wire-cut cookie baking, including time-lapse photography, were shown to be valuable as predictive research tools for guiding the successful mitigation of the detrimental effects of sucrose replacement, thus enabling the production of healthier cookies with the same product eating-quality attributes as ordinary cookies formulated with sucrose.

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