A Comparison of the Effect of Different Polymorphic Forms of Lipids in Breadmaking

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ABSTRACT

Adding fat crystals to a wheat flour dough increases the loaf volume; this study investigated the physical state of added fats during breadmaking. Fats in different polymorphic forms were added to doughs that were baked in an electric resistance baking chamber. In addition, an L2-phase, a so-called microemulsion, was used. A kinetic study, with different temperature rates, was also performed. The β-form increased the bread volume in a pronounced way and more than the other fat polymorphic forms. An addition of lipid in L2-phase makes only a minor contribution to loaf volume.

Numerous studies have reported on the role of lipids in baking (Carlson 1981, MacRitchie 1983), but the physical state of fats added to a wheat flour dough has not been systematically investigated. Baker and Mize (1942) reported that a 1:10 ratio of crystals to liquid improves loaf volume. Hoerr (1960) found that the polymorphic state of added fat has a marked effect on the loaf volume, and Mahdi et al (1981) reported the same effect. Carlson (1981) found that a phospholipid in a liquid-crystalline phase improves the loaf volume.

In this study, triglycerides in different polymorphic forms (α, β', and β) in liquid phase and in the L2-phase were investigated. All baking experiments of wheat flour bread were performed in a resistance oven. This technique was introduced by Baker (1939) and improved by Junge and Hoseney (1981).

MATERIALS AND METHODS

Formula

The wheat flour was an industrial standard mixture comprising several Swedish varieties milled at Skånemöllan, Sweden, and the composition was (in weight percent): protein 9.7 (N × 5.7, Kjeltec AN 19-79), lipid 1.0 (Soxhlet 6 hr petroleum ether extraction), water 15.0 (method 14.003, AOAC 1984), and ash 0.5. The falling number was 240. In the baking formula, the ingredients (based on 100 g of flour) were: yeast, 4 g; sugar, 2.5 g; salt, 0.05 g; and when added, lipid, 2.0 g. The amount of water was adjusted in the farinograph (Brabender C10) to obtain the elasticity expressed as 400 Brabender units.

Lipids

Hydrogenated rapeseed oil (LOBRA 40), stable in β-form, and soybean oil were both obtained from Karlshamns Oljefabriker, Sweden. A hydrogenated rapeseed oil with a high palmitic acid content (C-16 LOBRA 40) was also used in this study and was found to be quite stable in the β'-form (Hernqvist et al 1987). To obtain a stable α-form, an acetic acid ester of a monoglyceride from fully hydrogenated lard or tallow from Grindsted Products, Brabrand, Denmark, was used. A technical monoglyceride, Dimodan LS (Grindsted Products) was used in forming the L2-phase. Dimodan LS is a distilled monoglyceride prepared from sunflower oil. To determine the polymorphic state, X-ray diffraction was used, with results shown in Table I and Figure 1. The L2-phase was formed by mixing the monoglyceride and soybean oil in a 7:3 ratio (w/w), a composition that incorporated a maximum amount of water (11%) in the L2-phase (Fig. 2) (Pilman et al 1980).

Dough Procedure

The flour and lipids were stored at 8°C and tempered to 23°C before baking. Samples of the lipid were also taken to determine the polymorphic state by X-ray analysis. Flour and lipid were mixed 1 min in a farinograph, and water with yeast, sugar, and salt was added. The dough was mixed for 5 min at 60 rpm and proofed at 30°C for 34 min. The dough was cut in one 250-g piece, molded by hand, and placed in the resistance baking chamber. The temperature during fermentations was controlled by voltage adjustments. The starting temperature was 26°C and after 30 min reached 37°C, when baking began. After 4 min at 100°C the baking process was completed. A continuous flow of nitrogen through the baking chamber was maintained during fermentation (4.3 L/min) and baking (7.5 L/min).

TABLE I
Polymorphic State (determined by X-ray), Solid Fat Content (pulse NMR[a]), and Melting Point for LOBRA 40, C-16 LOBRA 40, and Cetodan 70-00

Sample	Polymorphic Form	Melting Point (°C)	Solid Fat Content (%) at Different Temperatures (°C) 10	20	30	35	40
Hydrogenated rapeseed oil, LOBRA 40	β	40	84	66	35	19	10
Hydrogenated rapeseed oil, high palmitic acid C-16 LOBRA	β'	40	88	70	38	20	8
Acetic acid ester of a monoglyceride, Cetodan 70-00	α	37–70	...[b]	...	...	...	...

[a]NMR = Nuclear magnetic resonance.
[b]Not determined because of the higher disorder of the hydrogen protons in the monoglyceride.

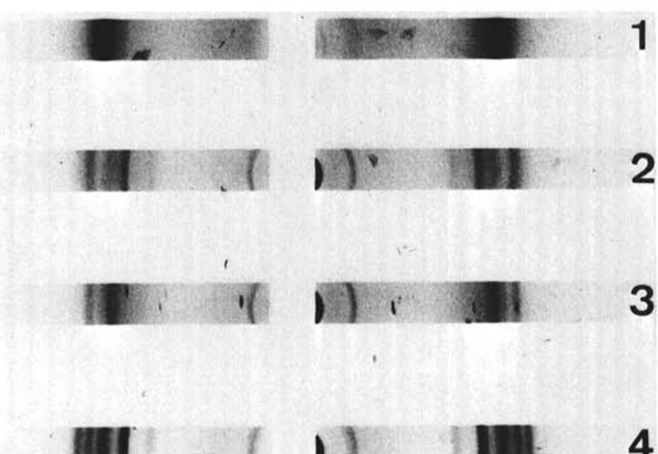

Fig. 1. An X-ray diffraction diagram showing the short and long spacings for Cetodan 70-00 (**1**), LOBRA 40 (**2**), C-16 LOBRA 40 (**3**), and Tristearine (used as a β-form reference) (**4**).

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Resistance Baking Chamber

The chamber was built according to Junge and Hoseney (1981) with minor modifications (Fig. 3). Height measurements were taken continuously using a photoelectric cell (JOS 022 Optischer analog sensor, Grieshaber, BRD). Height and temperature were continuously recorded versus time (Fig. 4). The electrodes were of

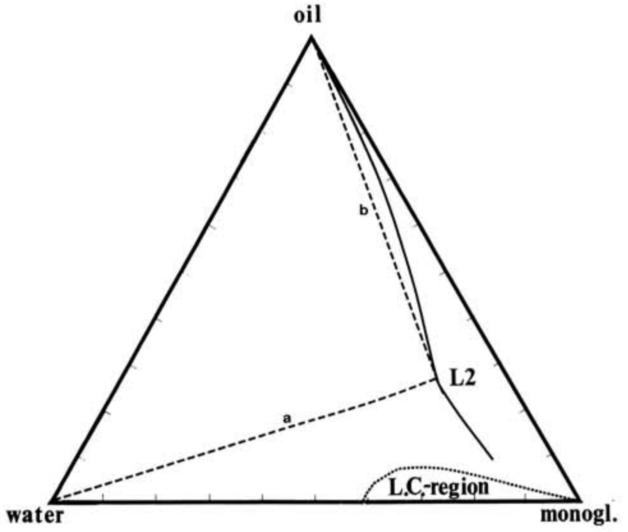

Fig. 2. An oil-water-monoglyceride ternary system diagram showing the L2-phase and the liquid-crystalline (LC) region. The LC region is dominated by a cubic phase. Line **a** is an equilibrium line for the L2-phase and water and **b** for the L2-phase and oil.

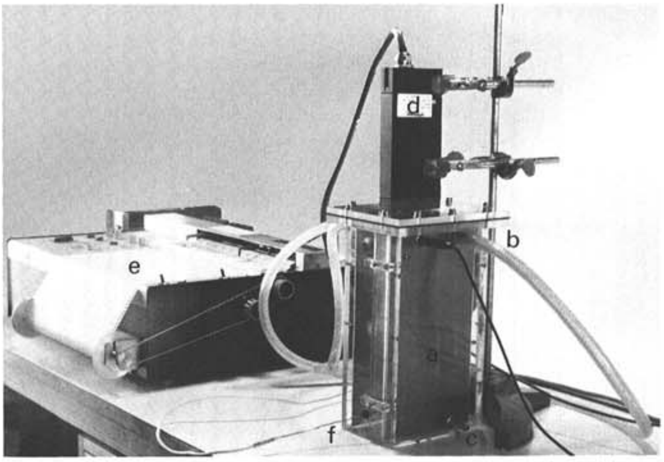

Fig. 3. The resistance baking chamber: the perforated steel plates (**a**), gas inlet (**b**) and outlet (**c**), the photoelectric measuring equipment (**d**), recorder (**e**), and thermoelement (**f**).

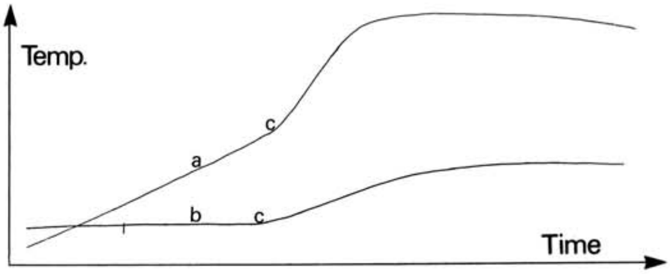

Fig. 4. Original recordings of the oven spring and temperature during baking, with an addition of 2.0 g of LOBRA 40 in β-form per 100 g of flour, height (**a**), temperature (**b**), and baking starts (**c**).

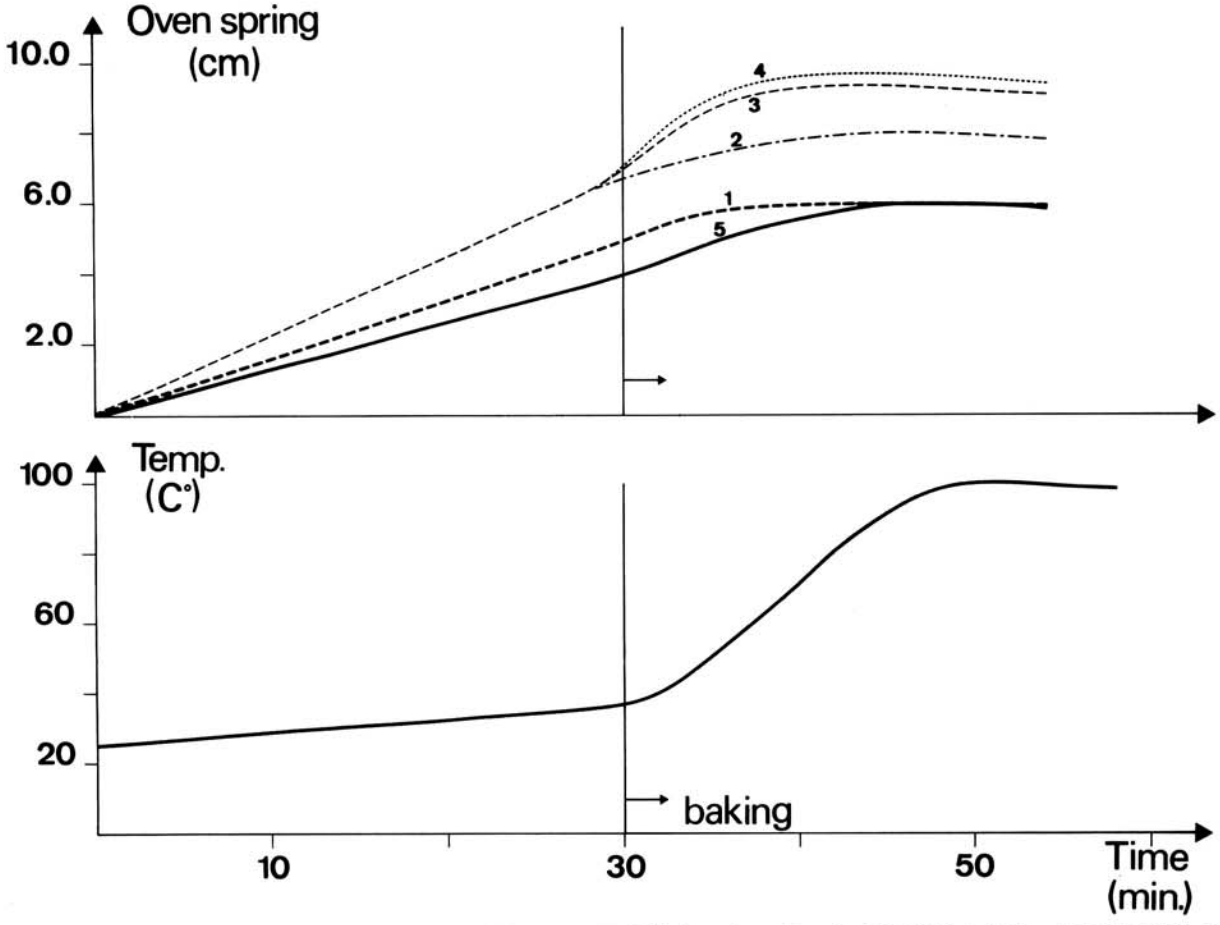

Fig. 5. Oven spring vs. time for baking experiments with no lipid added (**1**), lipids in α-form (Cetodan 70-00) (**2**), in β'-form (C-16 LOBRA 40) (**3**), in β (LOBRA 40) (**4**), and in liquid state (soybean oil) (**5**). The amount of added lipid was 2.0 g per 100 g of flour.

perforated steel plates (no special treatment was needed for the electric contact). Photographs were taken of the bread and photomicrographs of the bread crumb (1 g in 10 ml of water in normal and polarized light, ×400).

RESULTS AND DISCUSSION

Effect of the Physical State of the Lipid

The results of height measurements are presented as oven spring, defined as the height expansion in the baking chamber (the difference in centimeters between the maximum height of the bread and the height before fermentation). Oven spring results of different polymorphic forms of the added lipids in white bread are shown in Table II and Figure 5.

A pronounced improvement in volume was obtained when triglyceride was added in the solid state, whereas the liquid state gave no significant effect. It is also remarkable that the β-form was superior to β', which in turn was superior to the α-form. These

TABLE II
Oven Spring of Wheat Bread with Lipids of Different Polymorphic Forms in a Resistance Baking Chamber (means of three experiments)

No.	Lipid Character	Amount Added (g/100 g of flour)	Melting Point (° C)	Polymorphic Form	Time (min)	Oven Spring (cm)
1	None	···	···	···	27	5.95 ± 0.05
2	Acetic acid ester of monoglyceride fully hydrogenated lard or tallow	2.0	37	α	26	7.80 ± 0.05
3	Hydrogenated high palmitic acid rapeseed oil	2.0	40	β'	25	9.35 ± 0.10
4	Hydrogenated rapeseed oil	2.0	40	β	25	9.60 ± 0.15
5	Soybean oil	2.0	···	liquid		7.00 ± 0.10

TABLE III
Oven Spring of Wheat Bread with Monoglyceride, Soybean Oil, or a Monoglyceride/Soybean Oil Mixture[a] in a Resistance Baking Chamber (means of three experiments)

No.	Lipid Character	Amount Added (g/100 g of flour)	Melting Point (°C)	State	Oven Spring (cm)
1	None	0.0	···	···	5.95 ± 0.10
2	Soybean oil	2.0	2.0	liquid	7.00 ± 0.10
3	Monoglyceride/soybean oil, 1.4:0.6 g	2.0	25	L2-phase	6.90 ± 0.10
4	Monoglyceride	1.4	25	10% solid	7.40 ± 0.10

[a] Mixture forms an L2 phase with water.

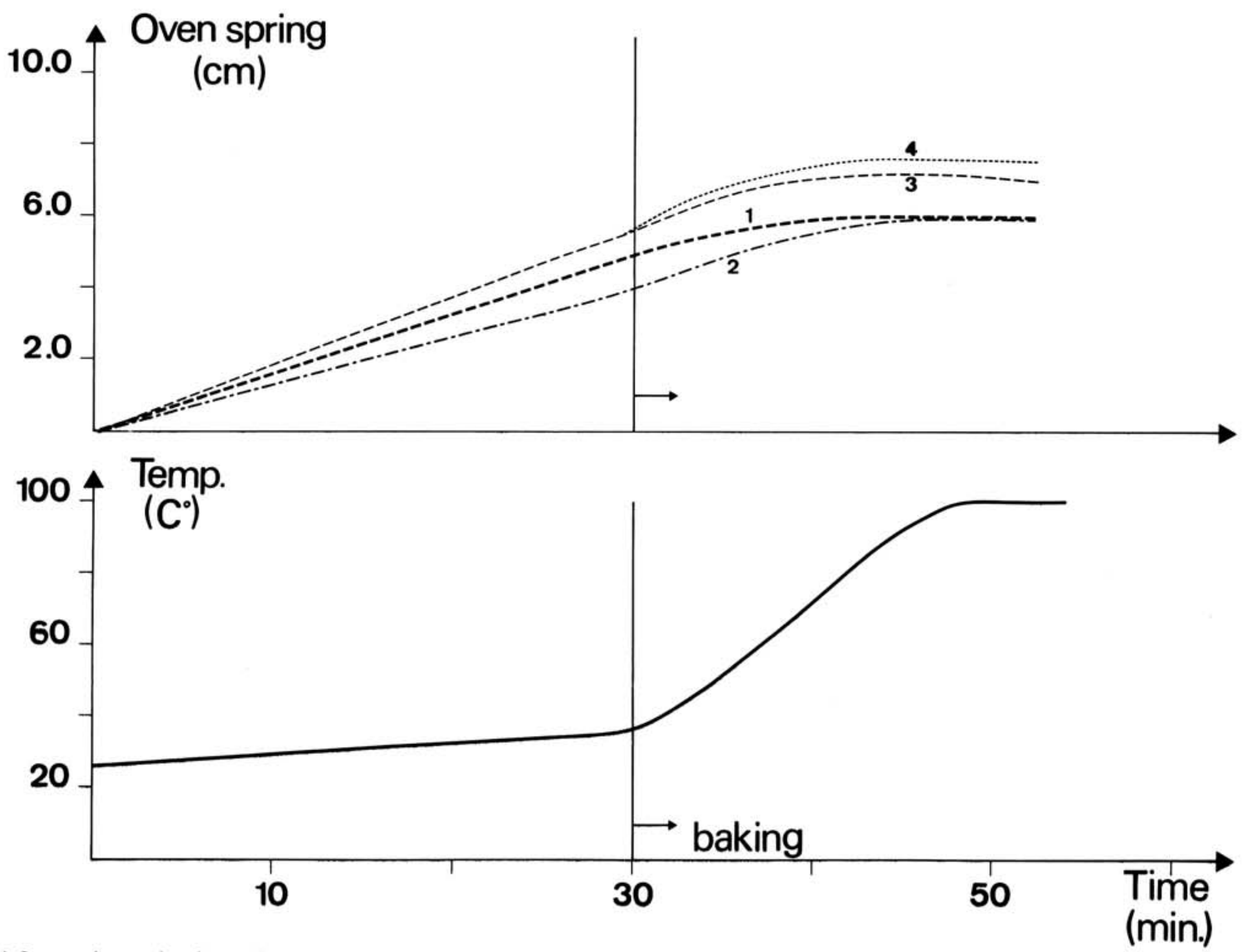

Fig. 6. Oven spring vs. time for baking experiments with no lipid added (**1**), liquid lipid (soybean oil 2.0 g) (**2**), L2-phase (monoglyceride/soybean oil 1.4/0.6 g) (**3**), and monoglyceride (Dimodan LS 1.4 g) (**4**).

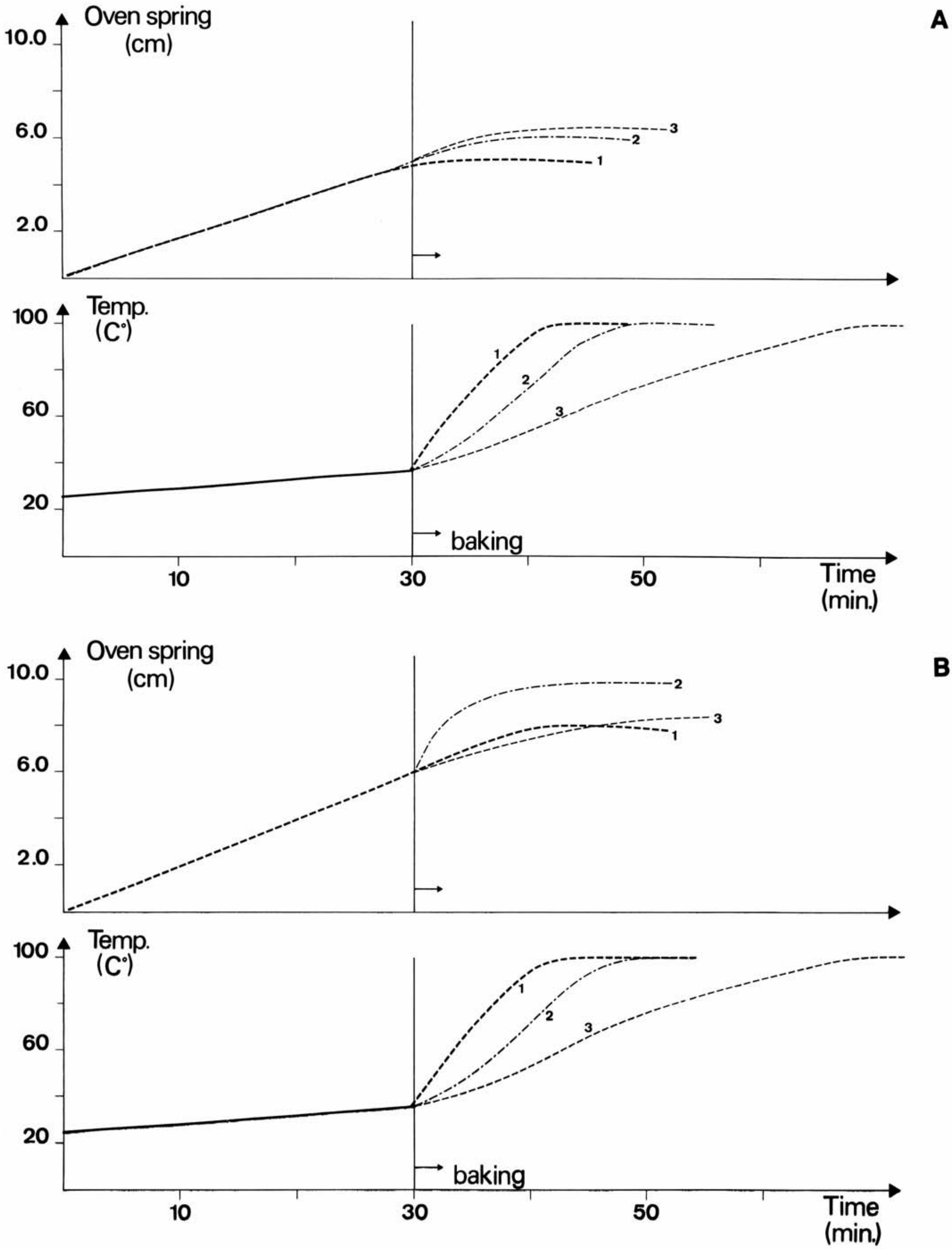

Fig. 7. A, Kinetic studies of oven spring expansion with different temperature rates, no lipid added. Temperature rates from 37 to 100° C were 12.5 min (**1**), 22 min (**2**), and 37 min (**3**). **B,** Kinetic studies of oven spring expansion with different temperature rates, 2.0 g LOBRA 40 in β-form per 100 g of flour added. Temperature rates were 12.5 min (**1**), 22 min (**2**), and 37 min (**3**).

results differ from those of Mahdi et al (1981); however, they used a different baking procedure.

The fact that a lamellar liquid-crystalline phase stabilizes the gas cell membranes (Carlson 1981), could indicate a similar effect on loaf volume by lipids in the L2-phase. The results are shown in Table III and Figure 6. The L2-phase is spontaneously formed when the flour and monoglyceride-soybean oil mixture is exposed to the water phase. The addition of soybean oil and monoglyceride was used as a control.

Addition of 2.0 g of soybean oil gave a small increase in oven spring. The L2-phase, however, gave a clear increase in volume. Using the monoglyceride only, i.e., there is no L2-phase but a cubic phase is formed (Larsson et al 1980), resulted in a further increase in oven spring. The results show that even if the L2-phase gave an increased volume, the polar lipid only resulted in an even better effect.

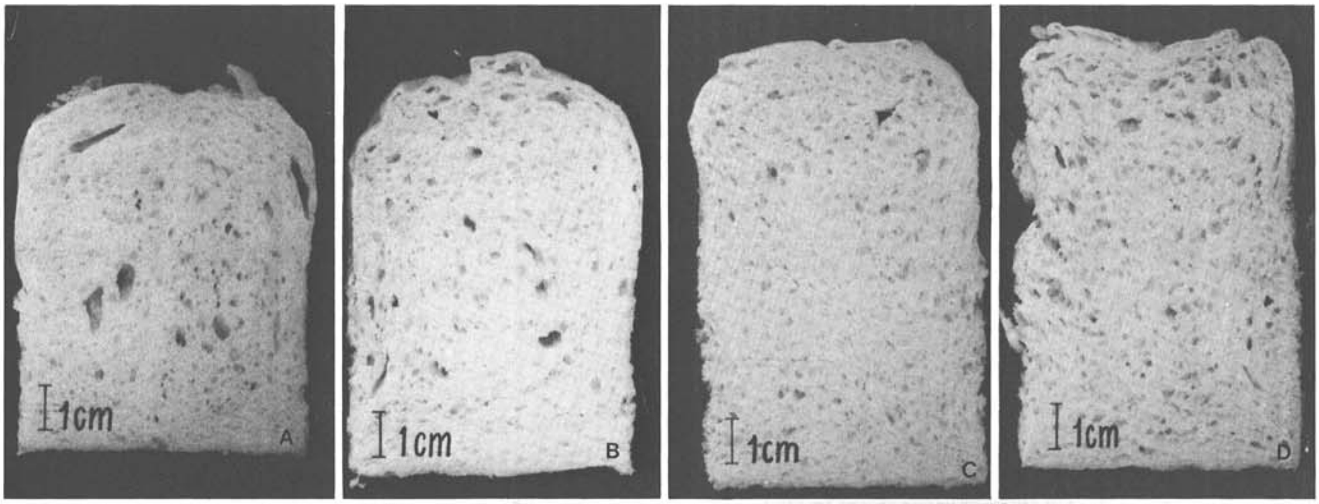

Fig. 8. Bread loaves with **A,** no lipid added (12.5 min), **B,** no lipid added (37 min), **C,** 2.0 g of LOBRA 40 (12.5 min), and **D,** 2.0 g of LOBRA 40 (37 min). Values in brackets are heating rates from 37 to 100°C.

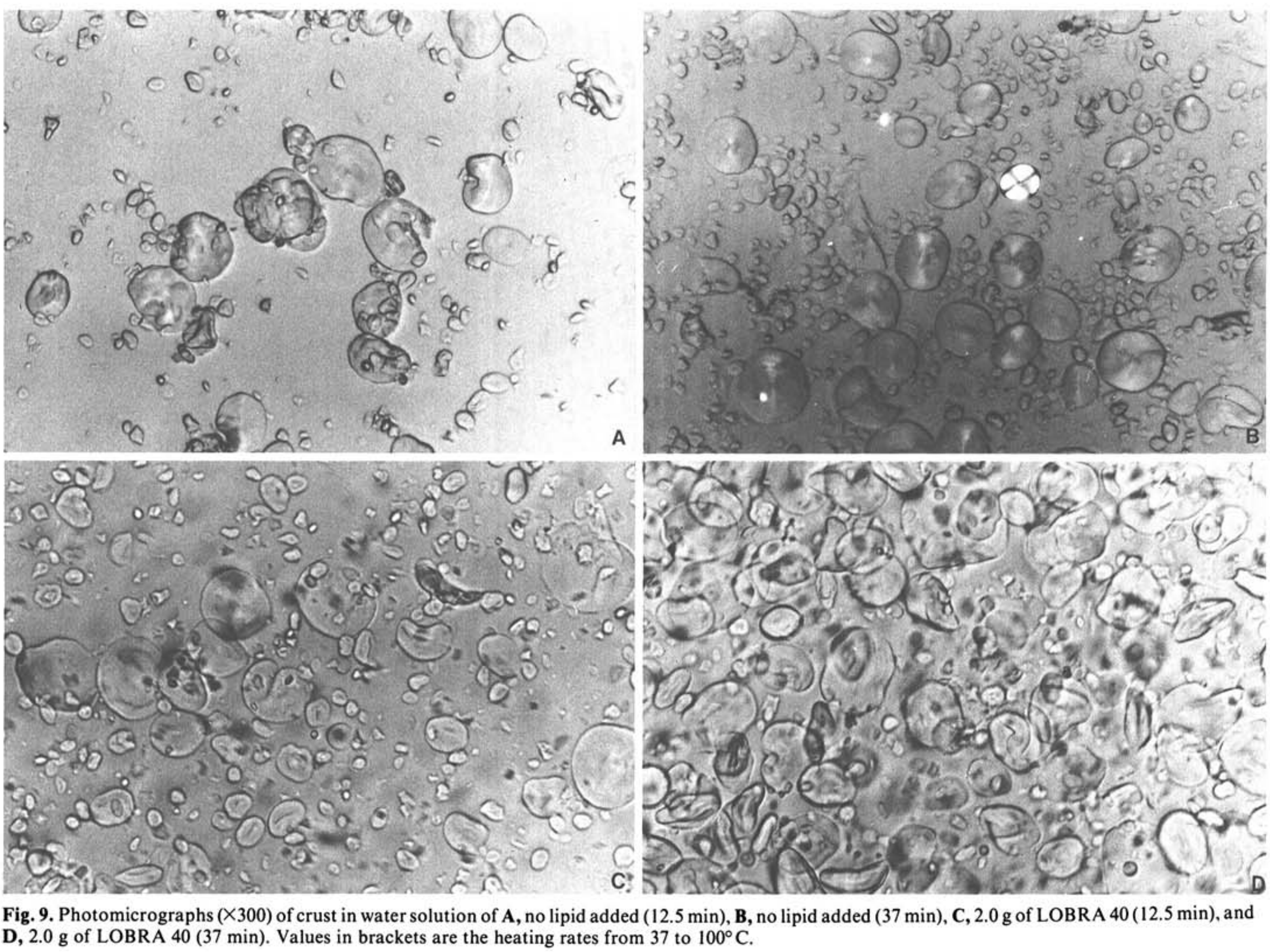

Fig. 9. Photomicrographs (×300) of crust in water solution of **A,** no lipid added (12.5 min), **B,** no lipid added (37 min), **C,** 2.0 g of LOBRA 40 (12.5 min), and **D,** 2.0 g of LOBRA 40 (37 min). Values in brackets are the heating rates from 37 to 100°C.

TABLE IV
Oven Spring of Wheat Bread with Different Baking Times, With and Without Added Triglycerides (means from three experiments)

Lipid Character/ No.	Amount Added (g/100 g of flour)	Baking Time (min)	Oven Spring (cm)
None			
1	···	12.5	5.00 ± 0.10
2	···	27.0	5.95 ± 0.10
3	···	37.5	6.35 ± 0.10
Hydrogenated rapeseed oil in β-form			
4	2.0	12.5	8.00 ± 0.10
5	2.0	28.5	9.60 ± 0.10
6	2.0	37.5	8.60 ± 0.10

Kinetic Studies

The baking chamber equipment makes it easy to vary the baking time and thus possible to study the kinetic factors involved in baking. In this work, baking time was controlled by using different voltage and time programs. Two types of doughs were studied, one with no lipid added and the other with added hydrogenated rapeseed triglycerides, mainly in β-form.

Three baking times were studied. The results are given in Table IV and Figure 7A and B. When no lipid was added, the oven spring showed a maximum at the longest baking time. With the β-form lipid added, the maximum was reached after 25 min.

Figure 8 shows the crust of bread with and without lipid at two different baking times. The texture is quite similar. The microphotographs show (Fig. 9) that the gelatinization of the starch is complete, even at short baking time. The effect of the lipids naturally present in wheat on baking performance was studied earlier at this institute (Carlson 1981). In these studies the dough was regarded as a foam, and the effect of the lipids was related to stabilization of the aqueous/gas interface. It is well known that oils in general destabilize a foam, and the lack of improvement by the oil used in this work is therefore not surprising. Fat crystals are not interfacially active, and the strong improvement when fat crystals are present should therefore be expected to be caused by a mechanical effect. Solid particles in foam lamellae always increase their mechanical stability.

The temperature at which expansion stopped with and without lipids present is fully consistent with the results reported by Moore and Hoseney (1985).

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