Practical factors influencing the shape of a cooked, flaked and formed beef product

PAUL D. JOLLEY[1], and W.R.D. RANGELEY[2]

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(2) AFRC Institute of Food Research - Bristol Laboratory, Langford, Bristol, BS18 7DY, U.K. and
Dalepak Foods Limited, Bedale, North Yorkshire, DL8 1UU, U.K.

Two of the most common complaints received by manufacturers of beefburgers and flaked and formed products in the U.K. concern the appearance of the cooked product. Firstly, shrinkage in planar dimensions suggests to the consumer a smaller portion than expected; weight loss may not be extreme since the product frequently increases in height ('doming'). The problem is greater with flaked and formed products, since ideally the cooked shape of reformed meats should be comparable to that of a whole-muscle cut. Secondly, puncturing the cooked product can release copious fluid ('welling') which is considered unsightly. We report two experiments aimed at assessing the relative effects of some processing factors thought to contribute to these problems, and the effects of reducing added fat and sodium chloride. The approach was one of initial screening to identify important factors, and in particular to determine any 2-way interactions.

Experimental

Experiment 1 - One 280 kg batch of a commercially-produced reformed steak mix was divided into 8 approximately equal samples immediately after blending and allotted randomly to treatment. Patties (approximately 114g) were formed from each sample on industrial forming machines of comparable throughput but different make and design, using moulds shaped as shown in Figure 1. All patties were frozen in a liquid nitrogen tunnel (20 m length, 660 mm width; Air products, Cheshire, UK). The treatments were:- delay between blending and forming (none; formed as soon as possible after blending: 35 minutes; held at -2°C for at least 35 minutes between blending and forming), make of patty former (Former 1, Former 2), and effectiveness of freezing (effective, ineffective: target temperature at core of product on leaving freezing tunnel <-10 °C and >-5 °C respectively) using a 2 x 2 x 2 factorial design. The order of forming and details of freezing are shown in Table 1. Core temperature was measured on one patty from each treatment as it left the freezing tunnel. Patties from all treatments were held overnight at -20 °C, packed in pairs and transported under refrigeration to the laboratory.

Experiment 2 - The experimental design was a half replicate of 2^5 (2^{5-1}) (Cochran and Cox, 1968). The five factors and their high and low levels are shown in Table 2, in the style of Hunter and Hoff (1967). The combination of factors to give sixteen treatments was according to Cochran and Cox, (1968).

Boxes (27 kg) of frozen beef forequarter were equilibrated to temperatures required at prebreaking over a sixteen day period. Other meat ingredients were mechanically recovered beef (11% addition to all formulations), and beef body fat (added at 12.5% at the expense of forequarter to high fat formulations). Meat was bandsawn, weighed into approximately 68 kg batches, and prebroken by grinding through a 35 mm plate on a Valiant grinder (Wolfking

Table 1. Experiment 1:- Delay before forming and observed temperatures on leaving freezing tunnel, arranged by order of forming

Treatment	Delay between blending and forming (minutes) Target	Actual	Former	Temperature at core of product Target	Observed
(A) 1	0	12	1	<-10	-11.6
2	0	14	2	<-10	-8.5
(B) 3	0	20	1	>-5	-6.0
4	0	27	2	>-5	-3.4
5	35	36	1	>-5	-7.0
6	35	37	2	>-5	-5.8
(A) 7	35	43	1	<-10	-14.3
8	35	45	2	<-10	-5.0

Notes:- (A) Maximum delivery of cryogen to tunnel
(B) Reduced delivery of cryogen to tunnel

Table 2. Experiment 2: Factors assessed and their levels

Factor		High level (+)	Low level (-)
A	Temperature at pre-breaking	-3 °C	-6 °C
B	Degree of comminution	coarse	fine
C	Amount of fat in final product (target)	20%	15%
D	Amount of added salt in final product (target)	1%	0.5%
E	Blending time	12 minutes	6 minutes

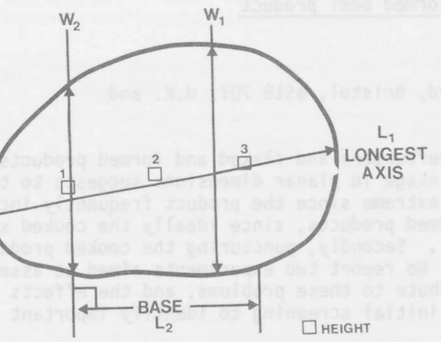

Figure 1 Shape of uncooked patties, and sites used for measurement. Heights 1, 2 and 3 were equidistant along an imaginary midline. The base (L2) is defined as the length of the comparatively straight region on the perimeter of the patties (more marked in patties from Former 2), and width 2 (W2) was taken perpendicular to the base at the narrow end of the patties. Width 1 (W1) was taken parallel to width 2 at the longest dimension in this orientation. The longest axis (L1) was actually about 15° off being parallel to the base. Marking of all sites was standardised using a template.

Danmark A/S, Slagelse, Denmark). Meat intended for fine comminution required an additional pass through a 10 mm plate. Prebroken meat was flaked using a Comitrol model 3600 (Urschel Comitrol, Valparaiso, USA) through either a 2-K-030240D (240; coarse comminution) or 2-K-030120D (120; fine comminution) head. Meat ingredients were transferred to a blender (Alitecno IP100, 36016 Thiene, Italy) and seasoning (0.6%), salt (1% or 0.5%), and water (1%) were added. Mixes were blended for 6 or 12 minutes. All blends were formed using Former 1 of the first experiment. The patties were frozen immediately in a liquid nitrogen tunnel and transported under refrigeration to the laboratory.

Patties were cooked from frozen using a standardised grilling procedure. Patties were marked using a template as shown in Figure 1. The initial planar dimensions, comprising two length measurements (longest axis, and base) and two width measurements (width 1 and width 2) and initial height at three equispaced positions (height 1, 2, 3) were measured.

Patties were cooked from frozen in batches of 4 (2 patties x 2 treatments) for 14.5 minutes with the upper surface initially approximately 55 mm beneath a pre-heated 2.7 kW radiant heat grill of a domestic electric cooker. Eight patties were cooked per treatment, and each was turned 4 times during cooking. Cooked patties were transferred to funnels attached to 25 ml measuring cylinders, each apparatus preweighed, and fluid released on puncturing collected in the funnel and cylinder for 2 minutes. Patties were removed, each apparatus reweighed and the weight of fluid released calculated by difference. Cooked patties were weighed and length, width and height measurements taken at the appropriate marks.

Results

The experimental designs do not allow comment on main effects when they are involved in significant interactions as the new variance ratio would be based on one degree of freedom in both cases. Results quoted are average values for the effect cited, across all other factors. The tables show only changes to the base, width 1 and height 2. Complete results will be presented elsewhere.

Terms used in expressing results 'Shrinkage' refers to comparative reduction in any or all of the planar dimensions (shrinkage = 100-mean $\left(\frac{\text{cooked dimension}}{\text{initial dimension}} \times 100\right)$), 'doming' means comparative increase in height at any or all positions (doming = mean $\left(\frac{\text{cooked height}}{\text{initial height}} \times 100\right) - 100$), and 'distortion' includes both shrinkage and doming. 'Welling' means weight of fluid (g) collected on puncturing.

'Cooking loss' = 100 - mean $\left(\frac{\text{cooked weight + weight of fluid}}{\text{initial weight}} \times 100\right)$

Experiment 1.

Actual delays between blending and forming, and observed temperatures at core of one patty on exit from the freezing tunnel are shown in Table 1. Patties formed at least 35 minutes after blending and intended for effective freezing (those of treatments 7 and 8) were produced 31 minutes after the otherwise corresponding patties formed as soon as possible after blending (treatments 1 and 2 respectively), whilst patties formed at least 35 minutes after blending and intended for ineffective freezing (treatments 5 and 6) were made only 16 or 10 minutes after the corresponding ones made as soon as possible after blending (treatments 3 and 4 respectively). Temperatures observed in the test patties were considered sufficiently close to their targets, with the exception of Treatment 8.

Selected means are shown in Table 3 according to treatment, and the level of significance of each main effect and all primary interactions are shown in Table 4.

Table 3. Experiment 1: Mean changes in selected dimensions and welling

Former		1				2			
Delay between blending and forming (minutes)		35		0		35		0	
Effectiveness of freezing (a)		+	-	+	-	+	-	+	-
Treatment number (by order)		7	5	1	3	8	6	2	4
Shrinkage	Base (%)	30	31	35	32	28	29	27	27
	Width 1 (%)	15	21	22	20	14	14	16	14
Doming	Height 2 (%)	23	31	41	33	12	14	8	9
Welling	Weight of fluid (g)	3.1	6.7	3.3	6.4	2.0	1.6	1.6	1.2

(a) + = effective freezing, - = ineffective freezing

Shrinkage of the base, width 1 and width 2 was greater in patties from Former 1 (32%, 19% and 18% respectively) than those from Former 2 (28%, 15% and 13% respectively). Patties formed as soon as possible tended to shrink more in width than those delayed 35 minutes between blending and forming, the effect being significant in width 2 (no delay = 18%, 35 minutes delay = 14%). The effect of delay between blending and forming on shrinkage in length depended on the former used but the magnitude of this effect was small (within 3% difference). Effectiveness of freezing interacted significantly with delay between blending and forming to influence shrinkage at width 1; shrinkage was greater in patties formed as soon as possible (19%) than those delayed at least 35 minutes between blending and forming (14%) if frozen effectively, whilst ineffective freezing caused 17% shrinkage irrespective of delay. All patties shrunk comparatively more in length than they did in width.

Doming was mainly influenced by an interaction between the former and delay between blending and forming. Doming at height 2 increased in the order-Former 2, no delay (8%); Former 2, 35 mins delay (13%); Former 1, 35 mins delay (27%); Former 1, no delay (37%), (least significant difference - lsd - = 5%) and this order of increasing doming was also found at height 1 and height 3.

Welling depended on an interaction between former and the effectiveness of freezing. Effective freezing of patties from Former 1 reduced welling markedly (effective = 3.2 g, ineffective = 6.6 g), but slighlty increased welling in patties from Former 2 (effective = 1.8 g, ineffective = 1.4 g) (lsd = 1.4 g).

Cooking loss - patties from Former 2 lost more weight during cooking than those from Former 1 (27.4% and 22.6%, respectively). Patties formed as soon as possible and frozen effectively lost 3-4% more weight during cooking than all other treatments.

Experiment 2.

The level of significance of important main and primary interactive effects is shown in Table 5. Only those factors or interactions with at least one significant effect as good as P<.01 are shown.

Shrinkage - patties with the higher level of fat shrank more than those with the lower level of fat, the effect being more marked with 0.5% salt. Finely comminuted patties tended to shrink more in length than those coarsely comminuted the effect again being more marked with 0.5% salt (eg longest axis: fine = 35%, coarse = 30%) than 1% salt (eg longest axis: fine = 30%, coarse = 28%). In general, patties with 0.5% salt shrank more than those with 1%. This effect was more noticeable with meat prebroken at -3 °C than with meat prebroken at -6 °C, and with patties of higher fat content than lower.

Doming was influenced primarily by the degree of comminution, but not in a simple manner. Coarsely flaked patties domed more at height 1 than finely flaked patties (coarse 48%, fine 39%), but less at height 2 (coarse 49%, fine 54%) and height 3 (coarse 43%, fine 50%). Finely flaked patties with 0.5% salt were particularly domed at height 2 (59%) and height 3 (56%).

Welling There was a highly significant (P<.001) interaction between temperature at pre-break and degree of comminution. In order of increasing welling, treatment effect was: prebreak temperature -3 °C, fine comminution (3.6 g); prebreak temperature -6 °C, coarse comminution (4.0 g); pre-break temperature -3 °C, coarse comminution (5.3 g); pre-break temperature -6 °C, fine comminution (5.6 g: lsd = 1.5 g).

Cooking loss Cooking loss for patties with the high level of fat was 29%, and 23% with the low level. Patties with 1% salt lost 24% during cooking, those with 0.5% salt lost 28%. Patties coarsely comminuted tended to lose less weight during cooking than those finely comminuted, the effect depending on the temperature of prebreaking (prebreak temperature -6 °C; fine = 26%, coarse = 26%; prebreak temperature -3 °C; fine = 30%, coarse = 24%).

Discussion

The 2 experiments have looked at specific examples of variation for each of the main unit operations used in the typical manufacturing of UK style flaked and formed beef patties ('reformed steaks'). Although it will be appreciated that details of raw materials and manufacture for Experiment 1 cannot be given because of commercial confidentiality, they are sufficiently close to those of Experiment 2 to be able to discuss both sets of results together.

The causes of distortion and welling have been shown to be highly interactive. This explains why the problems are not easy to control in practice, since interactive sources of variability would be difficult to identify under the conditions of commercial processing. Equally, few recommendations can be made that will minimise distortion or welling because each process should be considered in its entirety.

The greatest single influence was the former used (Experiment 1; see Table 4). Both machines use reciprocating plates for the final stage of forming, but otherwise differ in too many ways to be able to separate crucial differences from inconsequential ones. Orientation of gross connective tissue was visible on the surface of all patties, but the direction of orientation with respect to marked axes was different in patties from Former 1 to that seen in patties from Former 2. Shrinkage will be greatest in the direction of this orientation, and so some difference in distortion caused by the two formers might be explained. It is not yet clear how this orientation arises, or if it is important in determining doming or welling.

Changing the levels of several factors increased cooking losses. Reduction in volume through this mechanism inevitably confuses the effects of distortion, but in general factors causing greater shrinkage also increased doming. Contrary to expectations, increased doming was not always accompanied by increased welling; this can be best seen by contrasting the values for doming and welling in Table 3.

Manufacturers will usually specify the degree of comminution and levels of fat and salt for every product they make, but unacceptable variability still occurs. Assuming comminution, fat and salt to be constant, variability in distortion in patties from Former 1 could arise from poorly controlled temperature at pre-breaking, or different delays between blending and forming. The magnitude of this latter effect was unexpected. Poor control over temperature at pre-break will also lead to variability in welling, and inadequate freezing will increase the amount of fluid released. 'Overworking' (usually taken to mean excessive blending) is generally thought by industry to be a cause of distortion, but blending time was the least important processing factor in Experiment 2. However, there is little reason to suppose that the important factors identified for Former 1 are universally important.

Fine comminution led to greater shrinkage in length and increased doming at two positions. Jones et al (1985) noticed a tendency for increase in thickness during cooking of beefburgers to be related to collagen content (r = 0.4). Cuts with high collagen content are likely to be more finely comminuted, and it is possible that Jones et al (1985) were observing an effect of comminution rather than collagen content per se.

We were interested in the effects of reducing added fat and salt, in view of current concern about levels of both in meat products. The lower level of fat caused less shrinkage and less doming. Thus reducing fat will probably lead to less distortion. On the other hand, reducing salt will tend to increase distortion to an extent that will depend on the process followed, particularly with regard to degree of comminution and prebreak temperature.

Further studies on a similarly empirical basis will be of only limited general value since the high degree of interaction implies that results obtained on one system will not necessarily be applicable to another. The interactions also demonstrate why many of the reasons quoted by industry for particular production problems are often conflicting and unsubstantiated. The study has, however, established that more fundamental information is required, particularly on pre-breaking (for example, the effect of temperature on distribution of particle size and structural integrity) and the mechanism of forming, where a study of 'flow' properties of coarse comminutes is especially warranted.

Acknowledgements

The authors would like to thank Michael Hughes (Dalepak) for providing facilities and encouragement, and permitting publication of the results. Statistical design was by Dr H MacFie, who was assisted in data analysis by P Wallace, both of Statistics Section, IFR-BL.

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Table 4. Experiment 1: Level of signficance of main and primary interative effects

		Main Effects			Interactive Effects		
		Former	Delay between blending and forming	Effectiveness of freezing	Former x Delay between blending and forming	Former x Effectiveness of freezing	Delay between blending and forming x Effectiveness of freezing
Shrinkage	Base (%)	***					
	Width 1 (%)	***	X	(X)			**
Doming	Height 2 (%)	X	(X)	(X)	***		*
Welling	Weight of fluid (g)	X				***	

* P<.05; ** P<.01; *** P<.001

X Main effect significant (P<0.5 or better), but significant interaction with at least one other main effect

(X) Main effect not significant on its own but involved in one or two significant interactions

Table 5. Experiment 2: Level of significance of important main and primary interactive effects

		Main effects			Interactive effects			
		Degree of Comminution	Amount of Fat	Amount of Salt	Prebreak temp x Comminution	Prebreak temp x Salt	Comminution x Salt	Fat x Salt
Shrinkage	Base (%)	X	***	X			**	
	Width 1 (%)		X	X				***
Doming	Height 2 (%)	X	X	X			***	
Welling	Weight of fluid (g)	(X)	(X)		***	*		

See Table 4 for designation of symbols.