Cereal Foods World, January-February 2019, Volume 64, Issue 1

AACCI Approved Methods Technical Committee Report: Collaborative Study on the Cooking Time and Firmness of Spaghetti (Methods Report 66-51.01 and 66-52.01)

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https://doi.org/10.1094/ CFW-64-1-0118

ABSTRACT

The AACC International (AACCI) Pasta Products Analysis Technical Committee has completed a collaborative study of methods for measuring spaghetti fully cooked time (FCT) and cooked spaghetti firmness (absolute peak force, area to absolute peak force, total downstroke area, and total positive area). The methods have been approved as AACCI Approved Methods 66-51.01 and 66-52.01, respectively, after the collaborative study showed high reproducibility between labs testing the same samples.

Why a New Method for Measuring Spaghetti Firmness?

The complexity of training a sensory panel, due to subjectivity, low output, and sample quantity requirements, has led to the development of various instrument-based methods to evaluate the texture of pasta (3,6). Instrument manufacturers have provided guidance on applications for measuring the firmness of various foods, including pasta. The existing AACC International (AACCI) method (1) is based on the earlier work of Oh et al. (5). AACCI Method 66-50.01 (1) provides values for some parameters and instrument settings, but detailed scientific evaluation of the steps described had not been undertaken until recently. Preliminary comparisons of the application of the AACCI method by three different laboratories showed that the different cooking and instrument settings used by each laboratory significantly influenced sample rankings and that standardizing the method increased correspondence between laboratories (8). A detailed investigation of the effects of several process variables and instrument settings was conducted (4,7) and showed potential for improving this method to allow better reproducibility. It was concluded that a standardized method optimized to provide reproducible firmness results was needed to enable discrimination of textural differences among similar samples. Such a method would facilitate the comparison of results among quality control programs within the durum trade and pasta manufacturing industry and support international interlaboratory research studies.

The AACCI Pasta Products Analysis Technical Committee (PPATC) began work on development of a standard pasta cooking and firmness procedure in 2012, with a precollaborative study involving 8 laboratories (14 samples, 4 blind duplicates).The results showed promise for the method; however, it was noted that there was a laboratory bias and that the reproducibility between laboratories needed to be further improved (unpublished information). Despite good correlations between laboratories, there was still too much unexplained variation. More recent work (4) highlighted factors not considered in the earlier work. Therefore, the PPATC decided that further studies were needed to try to improve the method for determining spaghetti firmness, including

- Standardizing the cooking vessel (titanium pot with lid)
- Determining the need for cooling after cooking
- Using a standard probe (TA47) issued to all laboratories in the collaborative study
- Determining firmness as the mean of either 1 compression of the strands per cook × 3 cooks or 4 compressions per cook × 1 cook.
- Setting the cutting blade distance to 4.9 mm (0.1 mm away from the base)
- Using a consistent low pasta/water ratio to ensure minimum water temperature drop when the pasta is added to the cooking pot
- Using a single batch of commercial spaghetti produced by one supplier in sufficient quantity for distribution to collaborative labs as commercial 500 g batches can cause variation in sample uniformity and lead to variation in results

Participating Laboratories

The full collaborative study included 11 laboratories from 10 different geographic regions around the world with elevations ranging from 13 to 762 m above sea level. Analyses were completed in an 8 week time period.

Samples and Sample Preparation

Commercial in-house spaghetti samples (identified by sample number throughout) were sourced for the collaborative study (Table I).

Sample 1 was a commercial sample from a single processing batch; samples 2 and 3 were commercial samples from Nippon Flour Mills; and samples 4 and 5 were prepared at the Canadian International Grains Institute using a pilot pasta plant.

All samples were sent to the Tamworth laboratory in Australia for preparation for dispatch to the 11 laboratories participating in the collaborative study. Each bulk sample was mixed carefully to avoid breakage. From the mixed bulk sample, subsamples of about 200 g each were prepared, and the strands were cut into 7 cm lengths by breaking the strands by hand using a bench (described in Method 66-51.01). Samples were numbered 1–7, with no other identifying marks on the packaging, and sent to each laboratory with instructions for the test procedures. Two independent blind duplicates for samples 1 and 4 (samples 6 and 7, respectively) were included in the sample set. Participants were encouraged to practice the new method on their own spaghetti samples before proceeding with the test samples with the aim of achieving a within-laboratory repeatability relative standard deviation (RSD_r) of <6%. A video was also provided to assist labs with understanding the method.

Methods 66-51.01 and 66-52.01

The methods were written in AACCI style and provided to each laboratory with instructions to follow the method as written. There are two methods: 66-51.01, "Fully Cooked Time (FCT) of Spaghetti," and 66-52.01, "Determination of Cooked Spaghetti Firmness." Standard results sheets were provided for the FCT and firmness methods to record the data (Enhancement 66-51.01_Worksheet for FCT results and Enhancement 66-52.01_Firmness results sheet and macro commands). Each lab determined FCT and used their mean value for cooking time for measuring firmness. Raw data files from the instrument were sent electronically to the study coordinator.

The method, in brief, is as follows: cut spaghetti strands to 7 cm lengths and in three portions of approximately 8 g each; cook each portion to FCT in 250 mL of boiling water in a titanium pot and then cool in 250 mL of room-temperature water for 3 min. Recover the cooled spaghetti using a sieve and tweezers; align 5 strands of the cooked spaghetti on the texture analyzer base plate parallel to each other, spaced approximately 1 cm apart and perpendicular to the cutting blade. After 1 min, perform analysis. Clear the cut sample for the next two subsamples. Use the macro commands to calculate absolute peak force, area to absolute peak force, total downstroke area, total positive area, and cooked strand thickness. Calculate mean values of three determinations.

Collaborative Study

FCT Determination. Eleven labs participated in the collaborative study. However, some labs did not follow the instructions, performing either only one replicate determination of FCT (labs H, J, and K) or two replicates (lab C) instead of the replicate cooking procedures requested. Despite this, the results were used in the interest of pursuing the work. There was good agreement between the mean values of FCT for the blind duplicates for most labs. Outliers were identified using the Cochran and Grubbs tests according to AOAC guidelines (2). Because there was a Cochran outlier for Lab I for sample pair 4/7, this data was excluded from the analysis. Comparison across labs showed Lab F had the longest FCT values, and Cochran and Grubbs tests revealed a lab outlier for sample pair 1/6, so this data was omitted from the analysis. Lab F is at an altitude of 762 m above sea level compared with the other laboratories, which are at altitudes lower than 250 m above sea level. Water boils at ~97°C at 762 m; as a result, it would take longer to gelatinize the central starch core, which would account for the longer FCT for lab F. After removal of the outliers, the statistical performance of the method was calculated (Table II). Repeatability is a measure of the internal precision of a method. Two single results obtained within a laboratory under repeatability conditions (same technician using the same instruments in the same laboratory at the same time) should not differ by more than r. Reproducibility is a measure of the external precision of a method. Two single results obtained by two different laboratories under reproducibility conditions (different technicians using different instruments in different laboratories at different times) should not differ by more than R. Given the variables among laboratories (different equipment and slight differences in the application of the method by technicians), the reproducibility result incorporates many of the variables that are likely to be encountered during common use of the method. The reproducibility value obtained from the collaborative study was expected to be greater than the repeatability value. Both the repeatability relative standard deviation (RSD_r) and the reproducibility relative standard deviation (RSD_R) were very good given the degree of human interpretation needed to identify cooking time when using this method.

Statistical Analysis and Performance

Firmness Determination. The raw data files from the collaborative study were analyzed using a macro that gives estimates for five parameters: absolute peak force, area to absolute peak force, total downstroke area, total positive area, and cooked strand thickness. These are represented in Figure 1.

Lab H was included in the analysis for samples 1, 2, 3, 5, and 6, but not 4/7 (except for peak force) due to the presence of Cochran outliers. Repeatability and reproducibility values are shown in Table III. Cooked strand thickness was not included in the statistical analysis because it is not a measure of the texture of the pasta.

RSD_r values of ~1.9–3.4 indicate good repeatability when testing the same sample as a blind duplicate (Table III). Given the variables among laboratories (different equipment and slight differences in the application of the method by technicians), reproducibility results incorporated many variables that would be encountered during common use of the method. RSD_R ranged from 7.02 to 17.81%. A collaborative study of firmness of cooked pulses (8 labs and 13 samples) produced an overall average RSD_r of 4.3 and RSD_R of 6.31 (9). The values reported here are comparable for a food texture method. There were differences in RSD_r and RSD_R among the four parameters, with total downstroke area producing the lowest values, which is important for RSD_R across the samples (Table III).

No lab should be consistently higher or lower than the other labs if a method is truly independent. In this case (11 labs and 7 samples), no rank sum should be ($P < 0.05$) <19 or >65 (10). The ranks for labs by sample are listed in Table IV and illustrated in Figure 2, where rank 1 = the highest absolute value for the parameter. Labs C and D were consistently higher in downstroke (lower rank), while labs F and I were consistently lower in downstroke (higher rank). For peak force, labs D and E ranked lower, while only lab F ranked higher. For area and total area, labs C, D, and E ranked lower, while only lab F ranked higher.

These results show there were lab biases greater than measurement noise for the set of labs that participated in this collaborative study. The method may be considered valid if this bias is judged by the Approved Methods Technical Committee to be trivial, especially in light of the fact that the method will be mostly used for ranking pasta samples for their firmness within a lab instead of comparing absolute texture parameters among labs for the same set of samples. Looking at how each lab ranked the seven samples alone, there is generally good agreement. These rankings are comparable with the overall across-labs sample means (data not shown). Some concern may be associated with the blind duplicates (samples 1/6 and 4/7), because lab C separated sample 4 from 7, while several labs separated blind duplicate 6 from 1. A larger set of unknown samples with a wider range in firmness would present a better comparison of how labs ranked samples from firmest to softest.

Conclusions

The new method for determining spaghetti firmness has several advantages over the current AACCI method (1). For example, the new method provides more defined instrument settings and cooking conditions, which helps different users follow the test protocol as closely as possible to obtain comparable results for the same samples. Indeed, the correlation among the labs across the seven samples for each of the four parameters was excellent (for absolute peak force, area to absolute peak force, total downstroke area, and total positive area r^2 values were 0.881, 0.868, 0.981, and 0.974, respectively). The method also provides a macro that can extract more information from the compression test and a video to assist new users. Additionally, the method can be used when the sample size is small (e.g., as little as 8 g of spaghetti). Eleven labs participated in this collaborative study, testing seven spaghetti samples. The RSD_r values for FCT and firmness were <5%, indicating high precision. The RSD_R values for firmness ranged from 9 to 12% depending on the parameter.

Acknowledgments

We thank the following collaborative study participants for their excellent contributions and advice on method development: F. Manthey, North Dakota State University, Fargo, ND, U.S.A.; P. Ebbinghaus and E. Sopinwk, Canadian International Grains Institute, MB, Canada; D. Cassan, Institut National de la Recherche Agronomique, Montpellier, France; N. Alzuwaid, NSW Department of Primary Industries, Tamworth, Australia; H. Okusu, Nippon Flour Mills, Kanagawa, Japan; A. D'Alessandro, Barilla, Parma, Italy; B. Fu, Canadian Grain Commission, Grain Research Laboratory, MB, Canada; C. Fares, Council for Agricultural Research and Economics, Research Centre for Cereal and Industrial Crops, Foggia, Italy; A. Kiszonas and C. Morris, USDA ARS Western Wheat Quality Laboratory, WA, U.S.A.; C. Carter, California Wheat Commission, CA, U.S.A.; and C. Briggs, University of Saskatchewan, SK, Canada. We especially would like to thank Marc Johnson, Texture Technologies Corp., MA, U.S.A., for providing the cutting blades to laboratories and analysis of the raw data files and other advice throughout the collaborative study. We thank F. Ciancio, San Remo Macaroni factory, Windsor Gardens, SA, Australia; H. Okusu, Nippon Flour Mills, Kanagawa, Japan; and Paul Ebbinghaus, Canadian International Grains Institute, Winnipeg, MB, Canada, for provision of pasta samples. Thanks also to Anne Bridges and Paul Wehling for their useful comments on the statistical analysis and helpful advice on preparation of the report.

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Table I. Samples distributed to the participating laboratories

Spaghetti Sample	Sample Number
San Remo (2 mm diameter)	1
Nippon FM A (2 mm diameter)	2
Nippon FM B (2 mm diameter)	3
Canadian International Grains Institute (1.8 mm diameter)	4
Canadian International Grains Institute (2.0 mm diameter)	5
Blind duplicate of sample 1	6
Blind duplicate of sample 4	7

Table II. Performance statistics for fully cooked time (FCT) measurement of spaghetti cooking time

Parameter	Statistic[a]	Sample				
		1 and 6	4 and 7	2	3	5
FCT	nlabs	10	10	11	11	11
	Number replicates	20	20	11	11	11
	Mean (min:sec)	14:24	12:06	9:30	10:00	16:00
	RSD_r	2.1	2.4	0.64	0.90	0.94
	RSD_R	3.8	4.8	6.7	9.0	5.9

[a] RSD_r is the repeatability relative standard deviation, and RSD_R is the reproducibility relative standard deviation.

Table III. Firmness statistics for fully cooked time

Parameter	Statistic[a]	Sample				
		1 and 6	4 and 7	2	3	5
Peak force (N)	nlabs	11	11	11	11	11
	Number replicates	22	22	22	22	22
	Mean	9.02	9.61	9.66	5.79	9.70
	RSD_r	2.66	3.16			
	RSD_R	8.29	11.24	14.46	10.42	8.18
Peak absolute area (N × sec)	nlabs	11	10	11	11	11
	Number replicates	22	20	22	22	22
	Mean	4.40	4.40	3.74	2.38	4.79
	RSD_r	3.38	3.40			
	RSD_R	7.86	13.31	11.40	17.81	11.77
Total downstroke area (N × sec)	nlabs	11	10	11	11	11
	Number replicates	22	20	22	22	22
	Mean	5.67	4.61	3.69	2.98	5.84
	RSD_r	2.53	1.99			
	RSD_R	7.02	7.60	10.36	9.97	11.51
Total positive area (N × sec)	nlabs	11	10	11	11	11
	Number replicates	22	20	22	22	22
	Mean	6.01	5.17	4.24	3.26	6.34
	RSD_r	2.62	2.25			
	RSD_R	7.23	7.68	11.06	10.40	11.35

[a] RSD_r is the repeatability relative standard deviation, and RSD_R is the reproducibility relative standard deviation.

Table IV. Ranks for labs by sample[a]

Parameter Lab	Rank of Sample 1	6	4	7	2	3	5	Rank Sum
Peak force								
K	4	5	9	11	5	7	6	47
A	6	7	8	6	6	6	4	43
J	7	9	6	7	9	8	8	54
C	3	3	3	3	2	4	3	21
D	2	1	1	1	1	2	2	10
I	9	6	7	5	8	10	9	54
F	11	11	10	9	11	11	10	73
B	8	4	4	4	7	9	7	43
E	1	2	2	2	3	3	1	14
G	5	8	5	8	4	5	5	40
H	10	10	11	10	10	1	11	63
Peak absolute area								
K	7	4	9	8	5	6	9	48
A	6	8	8	7	6	7	6	48
J	8	9	4	4	7	8	8	48
C	2	3	3	2	1	4	2	17
D	3	2	1	1	2	2	3	14
I	11	6	5	5	10	11	7	55
F	9	10	10	9	11	9	10	68
B	5	5	6	6	9	10	4	45
E	1	1	2	3	3	3	1	14
G	4	7	7	10	4	5	5	42
H	10	11	11	11	8	1	11	63
Total downstroke area								
K	5	4	5	7	3	6	5	35
A	8	6	4	4	6	5	4	37
J	7	8	6	5	8	8	6	48
C	2	3	3	2	2	3	2	17
D	1	1	1	1	1	1	1	7
I	10	7	10	11	11	11	10	70
F	11	10	9	9	10	10	9	68
B	6	5	8	6	9	9	8	51
E	3	2	2	3	4	4	3	21
G	4	9	7	8	5	7	7	47
H	9	11	11	10	7	2	11	61
Total positive area								
K	6	4	8	10	6	7	7	48
A	8	7	5	4	5	5	4	38
J	9	9	6	8	8	8	6	54
C	1	3	3	1	1	2	1	12
D	3	1	1	2	2	3	3	15
I	7	5	9	5	10	11	9	56
F	10	10	10	9	11	9	10	69
B	5	6	7	7	7	10	8	50
E	2	2	2	3	3	4	2	18
G	4	8	4	6	4	6	5	37
H	11	11	11	11	9	1	11	65

[a] Rank 1 = highest absolute value for the parameter.

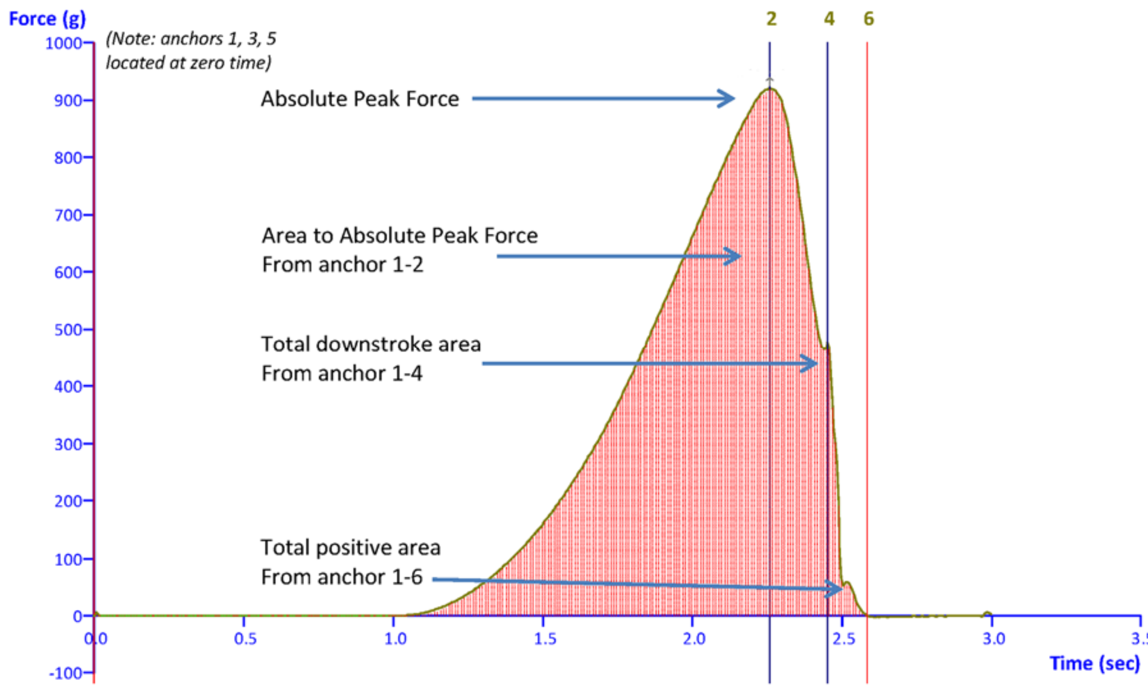

Fig. 1. Typical profile for firmness measurement, showing the parameters collected and the anchor lines (1–6) as vertical lines. Absolute peak force is the force at the maximum peak height of the curve (anchor 2); area to absolute peak force is the area between zero time and anchor 2; total downstroke area is the area between zero time and anchor 4; and total positive area is the area between zero time and anchor 6.

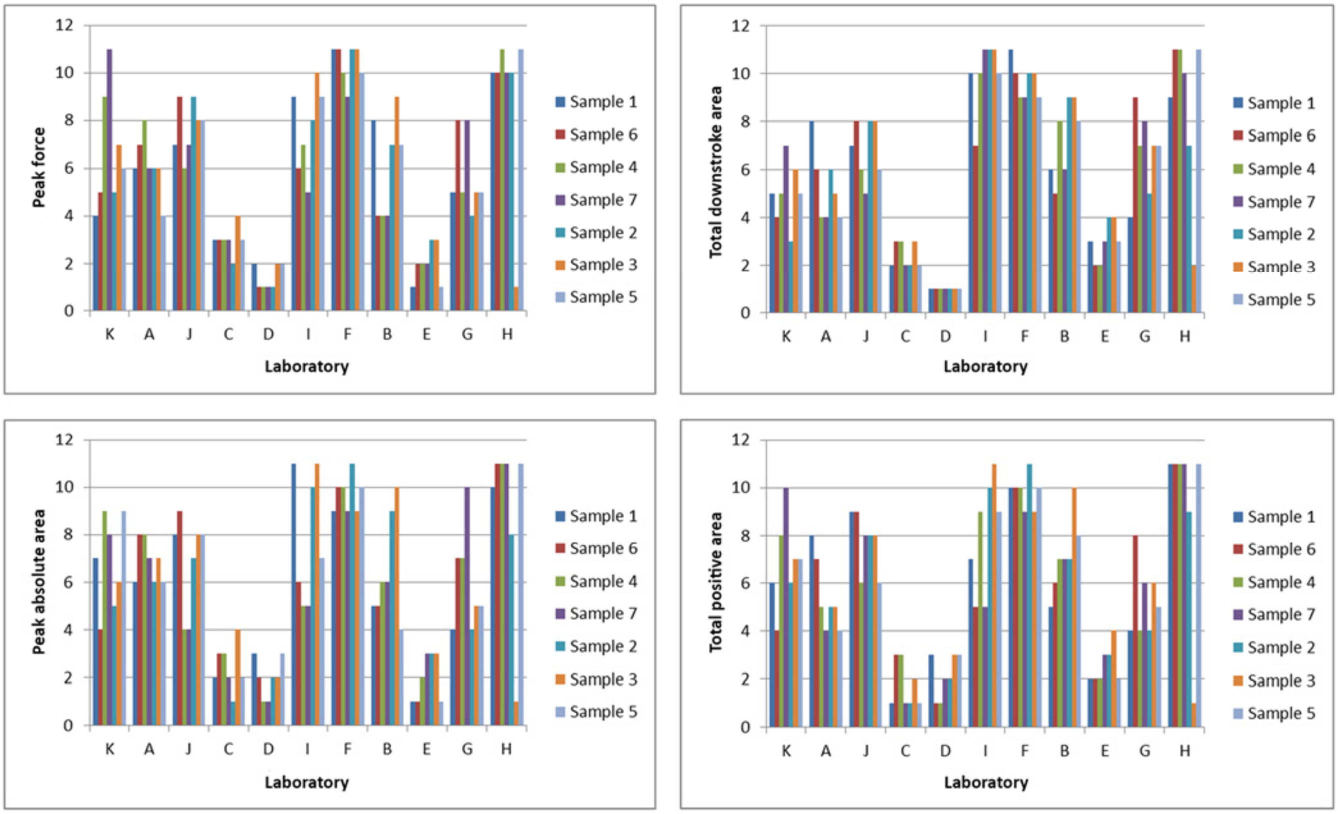

Fig. 2. Ranks for labs by sample. Rank 1 = highest absolute value for the parameter.