

PORK MARBLING

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For the last several years, a major drive has been underway to improve the lean to fat ratio of swine. Much has been accomplished in this conquest and we need to acknowledge the researcher, processor, producer and finally the consumer for the roles they have played in this advancement of red meat production. However, a high standard of living such as we are now experiencing in this country turns its attention not only to the desires of quantity but also to the quality aspects of possessions, and this is particularly true for food. Since our stomachs are limited in capacity, only so much can be "put away". Thus, when we amply satisfy our appetite and basic nutritional requirements, we lose interest in amounts of fuel, and launch a new program in search of higher octane propellants which will more completely fulfill the demands upon the palatability factors of flavor and aroma, juiciness, tenderness and general acceptability.

Unfortunately, the emphasis placed on lean pork has created a quality problem of the leaner muscle tissues which some have criticised for lacking tenderness and juiciness. Too, the soft watery pork problem has become a subject of more concern than in the past. Whether it has always existed or not remains questionable. Even though the price of pork greatly influences its production and consumption, it is my opinion that in the midst of our lucrative living, the American public has turned a cold shoulder to pork in lieu of its "less than the best" quality characteristics. Because this decreasing consumption of pork may be attributed to numerous factors, I am certain, therefore, that it would be extremely difficult for me to successfully prove this opinion.

Marbling, is among the factors of age, color and firmness that is presently receiving attention as a possible candidate which might be responsible for a higher quality pork. At present, there are several meat research groups actively engaged in the investigation of this constituent, and there are undoubtedly others who are beginning or planning to set up studies similar to those now in progress. It is the purpose of this presentation to discuss pork marbling from the viewpoints of consumer knowledge and acceptance, experimental findings in its association with subjective and objective palatability measurements, methods of predicting marbling content, basic concepts related to its character in the live animal, some chemical and histological considerations, problems encountered which may place the law of diminishing returns on its usefulness and finally some possible experimental approaches for future research.

Before going further, I would like to define marbling as any visible fatty tissues which are entwined around the muscle bundles and fibers within the structural framework of muscle tissue. To be more specific, it is my opinion that the term internal muscular fat would be

more appropriate in that it would also encompass the invisible lipid compounds which are included when organic solvent extraction is performed. Such constituents as all intracellular fats and some lipomorphic fats would then be given credit for their obscure presence.

1. CONSUMER ACCEPTANCE OF MARBLING

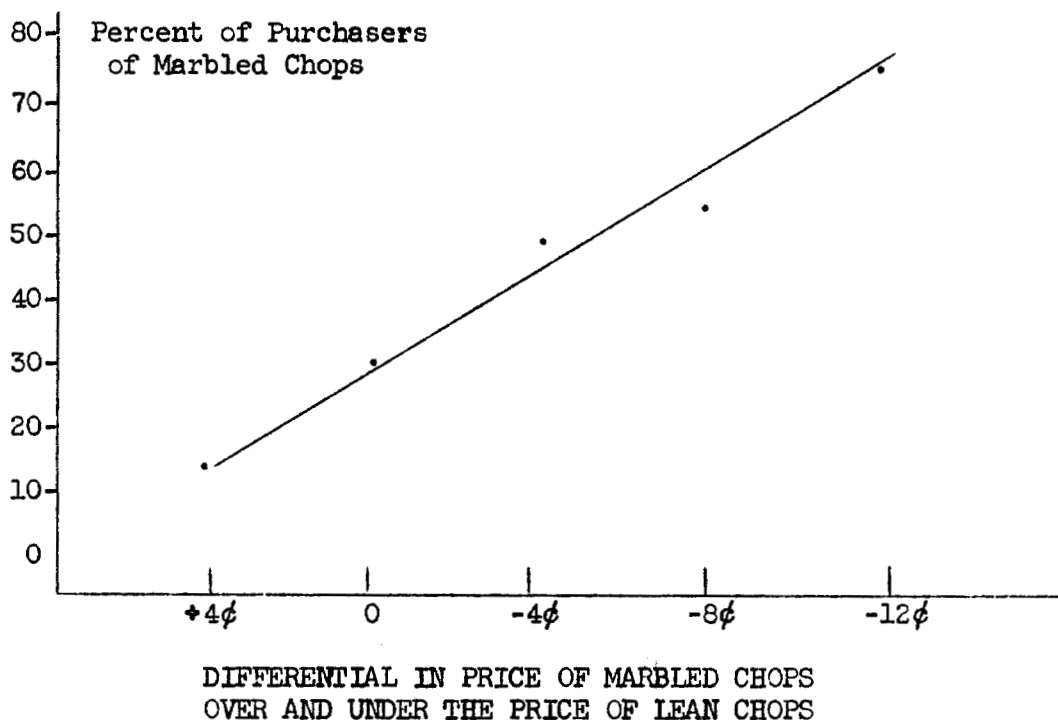
To the best of my knowledge, only one attempt has been made to measure the consumer desirability of marbling content in pork. The Wisconsin workers (18) conducted a project in 1957 to study the effect of price differential on marbled and unmarbled pork chops. Part of the program included a take home taste test in which participants were asked to compare the two types of chops. After 1800 customers had filed by a local meat packer's market showcase, 213 had entered the test by buying one of the two types displayed. The survey was divided into five units, each unit having a different price relationship between type of chops. The five market schedules included identical prices for both trays, a four cent differential, an eight cent differential and a twelve cent differential, all of which gave the marbled chop the lower priced mark. The final schedule paralleled the second schedule except that the four cent lower price was associated with the unmarbled chops. The thought behind such a pricing mechanism was to assume, from earlier studies, that people did not prefer fat and that the marbled chops thus indicated such and would probably receive criticism. The purpose was to measure the price consciousness of the customer and to note the severeness of differential necessary to stimulate buying toward the marbled cuts, even though size of loin eye, color and outside trim were held constant. The first slide* portrays the results of this market situation. There was a very consistent relationship between price differential and percent of marbled chops selected. The five points on the graph illustrate the closeness of fit with each change in price. When there was no difference in price, only 29% of the participants selected the marbled chops and when the lean chops were four cents lower in price than the marbled, only 12% bought the marbled. As the price of marbled chops was reduced below that of the lean chops larger numbers of buyers favored the marbled. Purchases were completely reversed from the lean to marbled chops at the twelve cent differential. Price was the predominant reason given for the selection of the marbled chops while leanness and appearance were the two main reasons given for lean chop selection.

As a result of the home taste test, 62% preferred the marbled chops as compared to 18% for the lean chops, while 20% indicated no preference.

In the telephone interview, less than half of the participants knew what marbling was. If the person did not know, the answer was supplied and then she was asked the importance placed upon it. Again, less than half of the participants indicated their likes for pork marbling.

It is apparent from this study that a definite preference for lean, unmarbled chops existed among these purchasers; that marbled

THE EFFECT OF PRICE DIFFERENTIALS ON THE SELECTION
OF MARBLED OR UNMARBLED PORK CHOPS (213 PURCHASES)



chops must be reduced considerably in price to induce buyers to purchase the same; that although the taste reaction to marbled cuts indicated a preference for them and although the participants commented that they would be willing to pay more for the marbled chops, these indications were not carried over to the purchase counter.

There are many limiting factors connected with this study and possibly many of the answers supplied here would not carry over to the population. However, it is my opinion that the reactions given here are a start in the direction of pork quality consumer research and it is my hope that larger and more complete studies will follow to verify or refute these findings.

2. A SUMMARY OF STUDIES MEASURING THE ASSOCIATION OF PORK MARBLING TO VARIOUS QUALITY FACTORS.

Next, I wish to briefly cover the contributions made in attempting to elucidate the variations of quality tests directly or indirectly associated with marbling content. Most of the studies reported in the literature have used either the loin or certain ham muscles as the experimental source. Studies by both Weir (29) and Mackey (23) have cited the problems involved in using the loin in meat studies; however, the reports indicate that after allowances are made with reference to the extreme variability in various

positions within the muscle, it can be used successfully. These positional effects can usually be handled by means of an appropriate experimental design.

Roasting, broiling and deep fat frying are three popular methods of research cookery; however, more investigations are badly needed to ascertain which of these methods would be best for experimentation. One train of thought suggests that the meat should be prepared similarly to that cooked by most housewives, whereas, others believe that a method which will more accurately and properly prepare the samples to demonstrate differences is necessary. For example, if one burns all the cuts to a crisp, as do some brides, I am afraid that the end product would be quite homogenous. This is a rather unfair analogy; however, it points out the fact that the preparation is by no means a simple task when attempting to bring out any differences which might exist. The deep fat frying technique has been used with some degree of successfulness; yet it is questionable as to its complete validity - especially when marbling has been considered. If marbling is important, this method may partially mask the characteristics of intramuscular fat and thus destroy differences that might very well persist when other more popular techniques are used. These are but a few of the difficulties arising in the cooking procedure.

On the following two slides, I have compared the organoleptic and objective findings which have been studied in relationship to fat content in the muscle tissue. Relationships between visual marbling score ratings and ether extracts have also been included*. The first of these two slides shows the four studies based on pork roasts. Batcher and Dawson's (31) work at the USDA on 12 pork loins indicates that the degree of marbling in the raw loin shows promise as a means of predicting the tenderness and juiciness of cooked loin and ham cuts.

SUMMARY OF STUDIES MEASURING THE ASSOCIATION OF
PORK MARBLING TO QUALITY FACTORS

R O A S T S

STATION	N	CUT	FLAVOR	JUICINESS	TENDERNESS	SHEAR	MARBLING SCORE
1. USDA	12	Loin		.91**	.86**	.28	.74**
2. USDA	12	Ham		-.23	-.32	.25	.66
3. AMIF	146	Loin	N.S.	P<.01	N.S.		P<.01
4. Iowa State	?	Loin	?	P<.01	P<.01		

SUMMARY OF STUDIES MEASURING THE ASSOCIATION OF PORK
MARBLING TO QUALITY FACTORS

L O I N C H O P S

Station	N	Type Cookery	Organoleptic			No. Chews	Objective		Marbling Score
			Flavor	Juiciness	Tenderness		Shear	Other	
5. MICHIGAN (1959)	75	Roast	← .31** →				-.47**	-.33**	
6. MICHIGAN (1960)	36	Deep Fat Fry				-.57**	-.62**	.85**	
7. OHIO (1960)	54	Broil	.10	.13	-.03			.76**	
8. WISCONSIN (2 Lean (1958) (2 Marbled)		Broil			5.4	28			
		Broil	4.5***		8.2***	38***			

They conclude that more than one muscle should be used to evaluate the quality because muscles vary so greatly. In their study with ham roasts, however, marbling did not seem to be related to the marbling of the loin, and as revealed in this slide the biceps femoris actually had a negative relationship to palatability factors.

Unpublished data from the American Meat Institute Foundation (30) show a good relationship of extractable fat to juiciness scores, but fail to give significant association with the remaining factors of quality. Murphy and Carlin (26) of Iowa State University have also studied marbling and report some positive relationships. The data were not available for this report, however, Professor Carlin indicated that marbling showed promise as an important factor in pork. It is the belief of this group that raw shear measurements and organoleptic testing are attempts to test two independent variables and thus should not be analyzed statistically as compatible measures. Wisconsin workers (19) seem to find some difficulty in using raw tissue as a reliable guide to palatability factors of the cooked meat. The second slide* relates studies made on loin chops. All of the data shown here appear to favor the presence of marbling; except for the Ohio work (16). In this exception, the correlation coefficients are extremely low and suggest that there may be other factors which should receive attention. The brief Wisconsin (18) study made as a pilot project in relation to the consumer acceptance report previously cited, was included to show the differences in mean palatability scores when extreme differences in amounts of marbling were compared. As one may note, all of the differences were highly significant. Most of the reports represented here have shown a very good relationship between percent fat as expressed by ether extract and marbling score. Even though degrees of marbling are rather simple to evaluate, I would estimate that the color and size of loin eye may contribute a good portion of the error in this subjective evaluation.

The next slide* shows the basic outline of the USDA pork quality study now being conducted at the Wisconsin station. The study is based

on the hypothesis that marbling and age may be two of the important factors for selecting higher quality pork cuts. The left hand side shows the degrees of marbling used and across the top indicates the two classifications of age. The first group includes four categories of pork based entirely upon carcass weight and equality in sex. The second part includes five known history groups.

Today, the study is only partially complete and much remains before a complete report can be made to prove or disprove the original hypothesis. For a preview of the progress now being made, I have extracted data which is fairly complete in the 155-170 pound unknown history group containing 54 pork carcasses. The next slide* gives the relationships found to marbling; however, I must caution you that these values are only preliminary in nature and should not be referred to until a complete report can be published. For those of you who are interested in the standard deviations of the cross products, I refer you to appendix I which will be available to you upon the conclusion of this morning's meeting.

Unfortunately, I am unable to explain fully the differences noted in the correlation coefficients of the gilts vs. barrows. Even though some of the values are in the range of significant magnitude, the general picture shows barrow values to be much lower than those of the gilt carcasses. This difference does not infer that marbling content in gilts is necessarily more important; however, it does seem to be a more accurate predictor of the quality factors. When one observes the means, the barrow carcasses consistently gave higher average scores in all measurements listed. This difference could partly be explained by the greater amount of extractable fat - if it is related to quality of the cooked muscles.

Project No. 1054
 USDA PORK QUALITY STUDY

UNIVERSITY OF WISCONSIN

Unknown History (pounds)

Known History (months)

125 B* G**		155-170 B G		200 B G		280-320 Sow	4-4½ B G		6-7 B G		9-11 B G		15-18 Sow	36-42 Sow

*B - Barrow

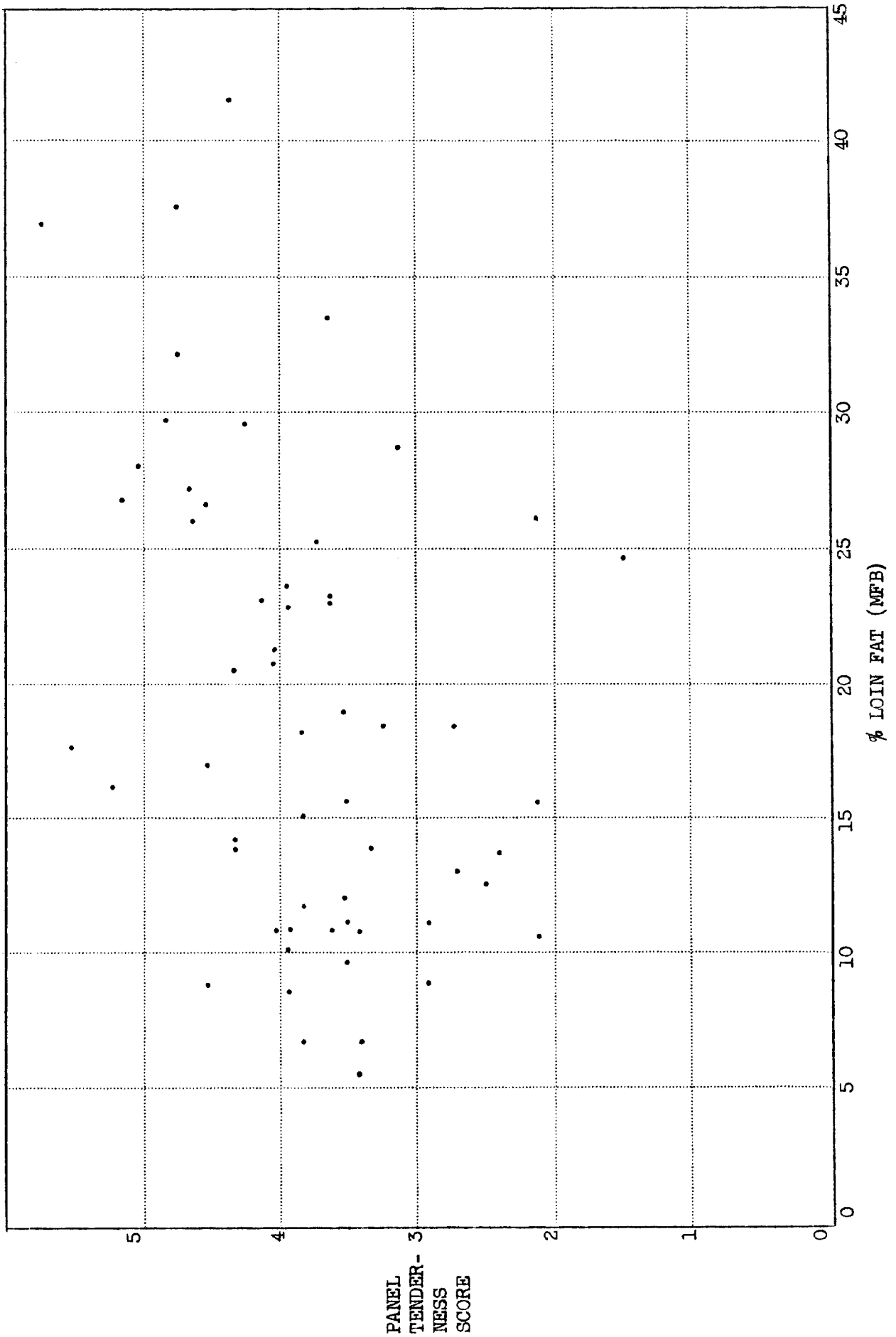
**G - Gilt

ASSOCIATION OF INTRAMUSCULAR FAT WITH QUALITY
MEASUREMENTS IN FRESH PORK LOINS (CARCASS WEIGHT = 155-170)

WISCONSIN - U.S.D.A. STUDY - 1960

A. <u>QUALITY FACTORS</u>		B. <u>SIMPLE CORRELATIONS</u>		C. <u>MEANS</u>	
% FAT (MFB) vs.:		<u>29 GILTS</u>	<u>25 BARROWS</u>	<u>29 GILTS</u>	<u>25 BARROWS</u>
MARBLING SCORE		.88**	.75**	2.9	3.1
TASTE PANEL	FLAVOR	.48**	.17	3.4	3.7
	TENDERNESS	.58**	.25	3.6	4.1
	NO. CHEWS	-.62**	-.41*	44.1	39.7
	JUICINESS	.82**	.54**	3.0	3.4
WARNER-BRATZLER SHEAR		-.58**	-.41*	8.6	8.2
ELECTRIC GRINDER (N = 18)		-.63**	-.40	.116	.097
		% FAT (MFB)		18.4	20.2

VARIATION BETWEEN TENDERNESS RATING AND PERCENT FAT IN THE PORK LOIN



The last slide of this series* gives you an idea as to the variability one may encounter when attempting to compare tenderness scores with marbling content.

At this time, it seems rather obvious that marbling must be associated in some way with overall pork quality. Even though it may not directly be the "driving force" for tenderizing and moistening the muscle tissue, it may act as a lubricating agent which helps to reduce friction and act similarly as No. 10 weight oil does to a cold, hard starting engine. Possibly, there is a combination effect in which marbling is one of the units and without the presence of its allied parts, it may not be affective.

3. METHODS FOR ESTIMATING MARBLING CONTENT IN PORK CARCASSES

If marbling in pork is established as a concrete quality factor, it would be imperative that a method be found to accurately predict its content in the carcass. At the present time, the loin is not cut as is the practice in beef, and unless this procedure should be altered, other carcass indications would be necessary. The following two tables show some of the experimental observations made in this area*.

Most of the studies have shown fairly low, yet significant correlations of marbling with average fatback thickness. It is rather logical that at certain stages of growth the various fat deposits should be related somewhat. However, Helander (13) and Callow (4) have found little relationship, particularly in older animals and people. This theory does not agree entirely with the Wisconsin work when the younger animals are considered, however, the extremely low correlation found in packer sow carcasses fit very nicely with the findings of Helander and Callow.

The Michigan workers (27) have shown very good results with specific gravity measurements and thus this could be used in experimental determinations, but would probably be unsuited for commercial use.

Wisconsin studies indicate that electrical resistance is correlated with percent fat in the loin, and does not lose this significance even after the effects of pH have been held constant. Since constant temperature is a rather critical requirement, this method would also be limited in its use.

It has been previously reported (17) that feathering and overflow might have some association with marbling. Even though the correlations were found to be of significance, the magnitude of them indicated that only a very small percentage of the variation in marbling was related to this external observation.

The marbling content in the lumbar lean* (multifidus dorsi and piroformis muscles) has been studied in the Wisconsin - USDA project and preliminary analysis has given the following highly significant correlations. It may be noted, however, that when a group of carcasses

METHODS FOR ESTIMATING MARBLING CONTENT IN PORK CARCASSES

A. <u>AVERAGE FATBACK THICKNESS X LOIN % FAT (MFB)</u>		<u>N</u>	<u>r</u>
1.	MICHIGAN STUDIES	75	.41**
2.	WISCONSIN STUDIES		
	GILTS	29	.55**
	BARROWS	25	.44**
	SOWS	25	.15
B. <u>FEATHERING--OVERFLOW SCORES X</u>			
	LOIN MARBLING SCORE	508	.26**
	HAM MARBLING SCORE	114	.32**
C. <u>SPECIFIC GRAVITY X LOIN % FAT</u>			
1.	MICHIGAN STUDIES	75	-.83**
D. <u>LUMBAR LEAN MARBLING SCORE X LOIN % FAT (MFB)</u>			
	GILTS	29	.86**
	BARROWS	25	.52**
	MISC. CARCASSES IN A NARROW FAT % RANGE (3.8)	32	.18 N.S.
			> .71**
REPEATABILITY OF MARBLING SCORES			
	LOIN	60	.87**
	LUMBAR LEAN	30	.90**
E. <u>ELECTRICAL RESISTANCE X LOIN % FAT (MFB)</u>			
	SIMPLE	33	.44**
	PARTIAL	33	.43**

are compared which have a small loin marbling variability, the correlation between lumbar marbling and percent fat in the loin was not significant. This would suggest that this technique could be best used in selecting for relatively large differences of percent fat in the loin. In the Wisconsin study, this technique has been used with some degree of success, yet some carcasses do not follow the pattern of similar intramuscular fat deposition*. The next slide shows five pork loins selected purely at random. The object was to select five loins which possessed the five different degrees of marbling in the lumbar lean. When the loins were cut at the 10th rib, the results were surprisingly accurate*. The only two scores out of place were 4 and 5, and thus, this could be explained on the basis of the previous correlations.

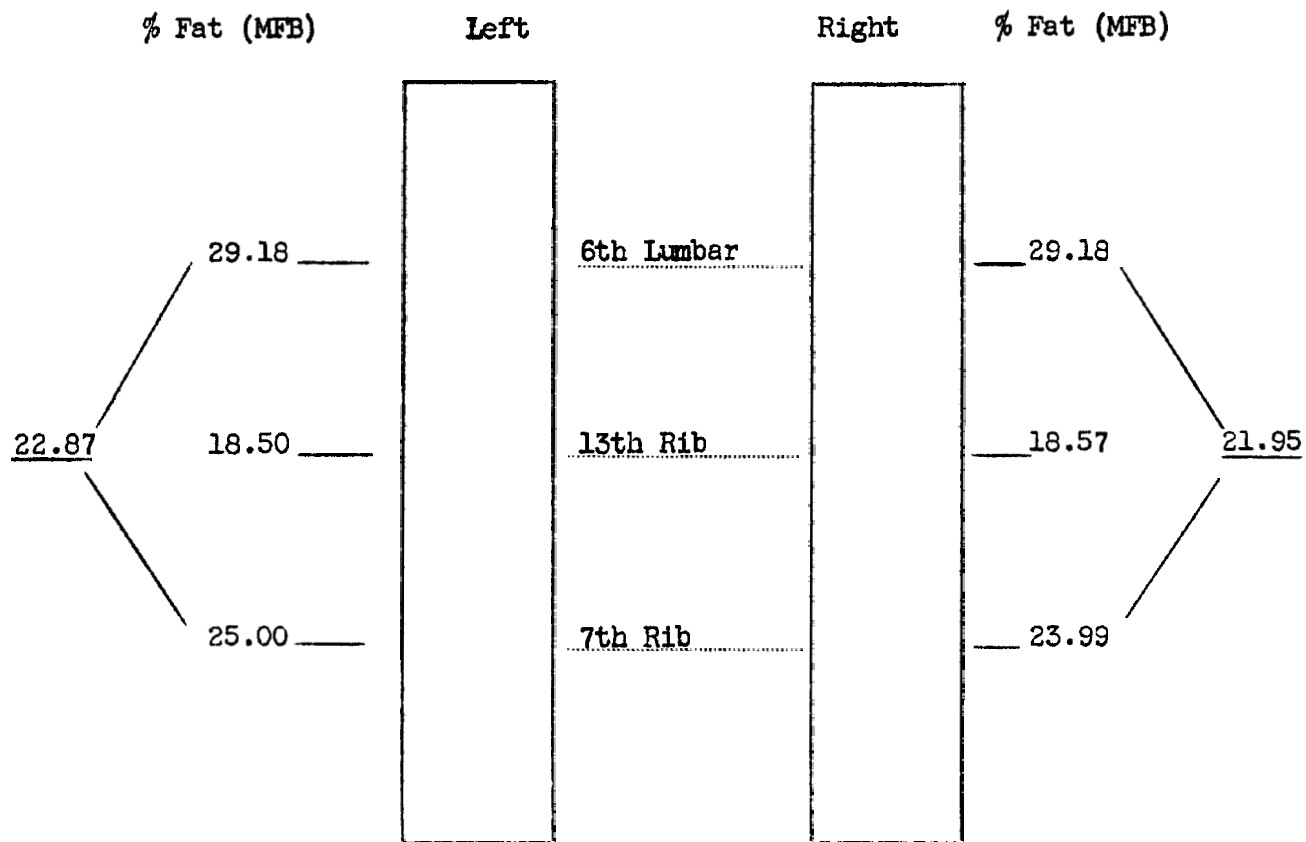
Possibly other indicators may be developed, such as ultrasonics; however, the techniques presented here appear to be the ones most considered presently.

4. MARBLING DEPOSITION IN SWINE

Now that I have scanned the field of marbling and its relationship to quality, I will give an enumeration of findings made which may give us a more complete picture of the marbling story.

- A. Wisconsin researchers have shown that, there are no differences in marbling content between right and left sides. This is in agreement with Helander's (13) findings in humans, (studied post mortem). However the variation of three positions within each loin was significantly different. This finding agrees very closely with the findings of Weir (29) who showed that posterior and anterior ends of the loin were more tender than the middle section (taste panel and shear). The combination of results of these two independent analysis speaks rather favorably for marbling as a factor concerned with tenderness. When each position was compared with the composite sample, the 7th rib position was most closely related to the total fat content of the loin; regardless of the fact that it too, was significantly different at the 5% level.
- B. Callow (3) reports that as growth and fattening proceed, the extra fat is laid down unequally. A larger and larger proportion of the fat goes into fatty tissues and a smaller proportion into the muscular tissues. As one would expect, the percent of fat in muscular tissue rises as the percent of fatty tissue in the carcass increases. This partially explains the correlations made on fatback and marbling in a previous table. Callow established a formula for calculating the rate of intramuscular fat which is: $.14 + .212 \text{ Fat tissue in Carcass} + C \pm 1.23$. ($r = + 0.762$). From this formula, he has shown the following ratios of fat in fatty tissue to fat in muscular tissue as total carcass fat increases.

INTRAMUSCULAR FAT DEPOSITION IN 27 PAIRED PORK LOINS



Range % Fat (MFB) Composite Samples = 10.77 - 36.20

STATISTICAL ANALYSIS

A. Analysis of Variance

1. Between right and left loins, $F = 1.101$ N.S.
2. Within all loins, $F = 51.81$ ***

B. Duncan's Multiple Range Test

1. Comparison between positions within the loin

	6th Lumbar	7th Rib	Composite
13th Rib	10.65**	5.96**	3.88**
Composite	6.77**	2.08*	
7th Rib	4.69**		

<u>Total Carcass Fat (%)</u>	<u>Fat in Fatty Tissue/Fat in Muscular Tissue</u>
15	3.5
20	5.4
30	6.9
40	8.4
45	9.0

- C. Some of the factors which may affect either the amounts or characteristics of marbling deposited are the nature of the ration fed, starvation, the endocrine balance, weight, age, breed, and season. Kelly (20) reported slightly lower but not significant values for loin and ham marbling when pigs were supplemented with aureomycin. The reverse of this was shown by Clawson (6). He also showed a lowering of mg percent blood fat due to antibiotic administration. In another part of the experiment, Kelly showed loin marbling to reach a maximum level at 125 pounds live weight; however, McMeekan (25)* found intramuscular fat to increase with age up to 28 weeks. This slide shows the results of McMeekan's findings. The decrease in deposition at the 16 week age is possibly due to the fact that during younger ages, muscle tissue is growing fast relative to fat, but that later the rate of fat deposition overtakes it. McMeekan's studies also show the change in position of deposition between the 8 and 16 week ages. This data further varifies the early work reported on the variation of marbling within the loin. As noted here, the iodine number is quite high at first and increases to 76 before being lowered at 16 weeks of age. McMeekan explains this phenomenon on the basis that during the early development, the young pig deposits very little fat but, that which is deposited comes from the sows milk which contains fat of lower saturation. After the pig begins to consume more protein and carbohydrate which may be converted into a more highly saturated fat, then the number goes down. This is only a suggestion as to the mechanism which may persist.

Kropf (21) has shown that high quality protein will produce a lower percent of marbling in the loin. He also shows a difference in sex with respect to marbling deposition. Regardless of age, weight or ration in most cases gilts had less percent fat in the loin than did barrows. In addition, Kropf's data agree with Kelly's in that the highest percent of extractable fat was found at a lighter weight. He indicated that at 145 pounds, the percent fat (MFB) was 18.9% as compared to 12% at 85 pounds and 17.6% at 205 pounds. Merkel (24) studied the effects of various feeding practices on changes in carcass composition and showed that the percent intramuscular fat in the loin could be decreased by feeding high protein rations, by limited feeding and by lowering TDN values, which was accomplished by adding corn cobs or alfalfa hay to the ration. As fiber content increased in the ration, lower percentages of intramuscular fat were obtained.

CHANGES OF INTRAMUSCULAR FAT IN THE LOIN
OF THE GROWING PIG (McMEEKAN)

AGE (wks.)	% TOTAL FAT	POSITION IN LOIN			IODINE NO.
		<u>Anterior</u>	<u>Middle</u>	<u>Posterior</u>	
Birth	1.9				71
4	4.3				72
8	4.7	8.5	4.2	2.0	76
16	3.4	4.2	0.7	1.3	65
20	4.0				58
28	5.6				60

In studies by Ellis and Isbell (9), it was shown that the fatty acids of intramuscular tissue in pigs could be increased in degree of unsaturation by feeding peanuts. Measures of refractive index were used to verify such differences. Blumer (1) has also shown similar effects of soybeans on carcass fat.

In January 1960, at the Wisconsin station, three Chester White pigs, weighing about 260 pounds were starved and given only water for a four week period. Previous to this stress, a biopsy sample was removed from the longissimus dorsi muscle at the 10th rib and analyzed for total intramuscular fat. A backfat probe was also initiated at this time. After a loss of 33 pounds, the pigs were slaughtered and samples from the loin were removed for chemical analysis. It was shown in this experiment that intramuscular fat was called upon as a source of energy to the tune of a 30% decrease. This decrease was rather closely associated with the 33% decrease in fatback thickness; however, in making such an analogy, one should keep in mind that a volumetric change is being compared to a one dimensional measurement. From results on previous controls, the chemical nature of the fats did not show a very decided change.

ANALYSIS OF INTRAMUSCULAR FAT AFTER STARVATION

NO.	% FAT (DRY BASIS)		% DECREASE	I ₂ NO.	SAPON. NO.	M.P. (C°)
	INITIAL	FINAL				
1	18.31	10.30	43.7	52	--	36.0
2	24.54	17.64	28.1	57	196	41.6
3	25.34	19.69	22.3	55	198	43.1
\bar{x}	22.73	15.88	30.1	55	197	40.2
Control	--	15.40	--	53	--	--

A COMPARISON OF MEAN VALUES FOR FOUR
DIFFERENT FAT DEPOSITS IN STARVED SWINE

TYPE OF FAT DEPOSIT	% DECREASE DUE TO STRESS	I ₂ NO.	SAPON. NO.	M.P. (C°)
SUBCUTANEOUS	32.6	61	196	45.8
INTRAMUSCULAR	30.1	55	197	40.2
INTERMUSCULAR	--	57	197	75.9
ABDOMINAL	--	62	196	46.3

Clawson (6) has shown a difference due to breed of the percent extractable fat of the carcass meat. Chester Whites, Berkshires and Yorkshires ranked in that order with regard to total fat content. Judge (15) concluded from studies on 321 pigs of six different breeds, that there was a highly significant difference when marbling was compared to breed. From his data one would rank the breeds (on the basis of the highest marbling content) as follows:

<u>Rank</u>	<u>Breed</u>	<u>Number</u>	<u>Ave. Marbling Score*</u>
1	Berkshire	29	3.6
2	Spotted Poland	41	3.1
3	Yorkshire	110	2.1
4-5	Poland China	40	2.0
4-5	Hampshire	48	2.0
6	Landrace	27	1.8

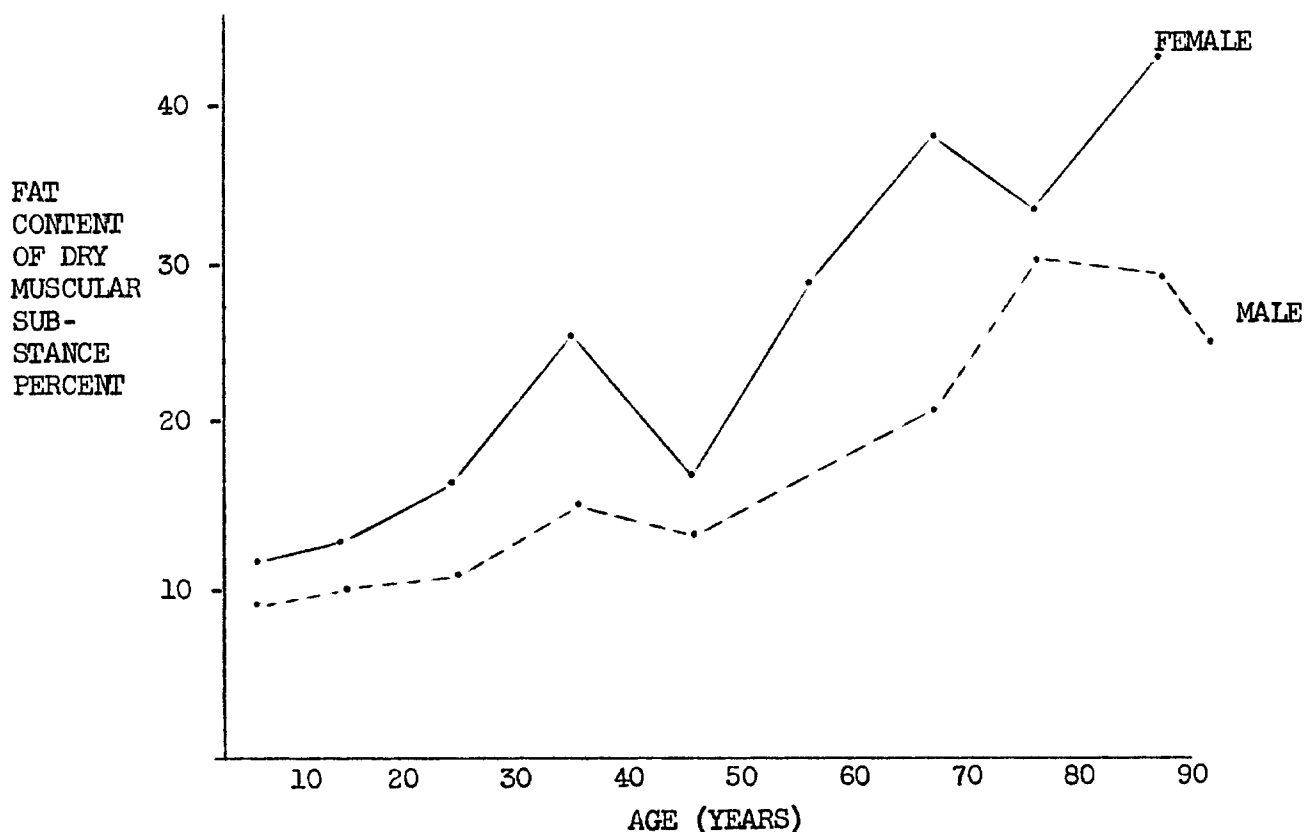
*based on slight = 1, moderate = 3 and abundant = 5

Judge also found that carcasses from hogs raised and slaughtered during the cool weather season possessed more highly marbled loins. His comparison of barrows vs. gilts failed to show any difference even though the correlation values approached the 5% level. This would tend to weaken the claims of other workers previously mentioned, since in their reports, there was a definite difference in all cases.

Age has also been considered as a factor which may effect total intramuscular fat. Judge (15) made such a comparison but his results suggested that age was not important to marbling. Helander (13) has shown, however, a very definite and positive relationship of age to muscle fat. Fat content of the median head of the gastrocnemius muscle in cattle, rabbits and horses showed significant increases when young were compared with old animals. He also showed a definite relationship in human muscle as indicated on the following slide*. Helander discusses this

relationship and the possible mechanisms which may explain the deposition of muscle fat. Unfortunately, time does not permit a complete discussion of the interesting thoughts projected in this paper.

FAT CONTENT OF GASTROCNEMIUS MUSCLE AT DIFFERENT AGES.
(HELANDER, 1959)



5. CHEMICAL, AND HISTOLOGICAL CONSIDERATIONS.

- A. It appears that intramuscular can be extracted completely and in a pure form by adding anhydrous sulfate salt to a previously ground preparation of fresh muscle tissue. This prevents moisture complexes with the organic solvent and thus will prevent contamination from normally insoluble constituents which may be carried along with the fat extract. This also eliminates the removal of moisture at high temperatures which would possibly alter the original characteristics of the fat to be studied. A chlorinated organic solvent such as chloroform has been suggested for more complete analysis; however, diethyl ether seems to be relatively effective if used at a low temperature. After initial extraction, the

ether is removed by evacuation at 40° C. and the residue fat is then redissolved in a solvent to eliminate any remaining contaminants which were extracted but which would not dissolve in the pure ether. After the second extraction and evacuation, the fat can be placed in a dark cold, storage unit in an airtight container to prevent undue oxidation until the sample is to be analyzed. Since the fat is a liquid at a relatively low temperature, it can be easily warmed to allow for transfer into laboratory equipment.

B. Histologically staining of fat has its disadvantages; however, with proper precautions one may be successful in the preparation of detailed slides. The preparation now used by Carpenter of the Wisconsin station is as follows:

1. The Muscle sample is fixed in formalin and then with osmic acid.
2. The sample is then sectioned at a thickness of eight microns.
3. The magnification is about 9.3×10^3 plus the projection magnification.

The next slide shows a section of loin muscle tissue which contained abundant amounts of marbling. The technique used for this preparation differed in that the sample was fixed in picric acid and then dehydrated and defatted with dioxan and alcohol and simultaneously infiltrated with hot paraffin. The light cells are the original fat cells.

In Helander's (13) report, he states that in the large majority of both human and animal muscles, the histologically estimated fat content closely approximated the fat content found by chemical analysis.

To say the least, this technique in studying marbling is quite time consuming. It requires considerable patience and a well educated technique. Of course, if we should compare it to electron microscopy, then we would consider histological preparation a more routine and less difficult proposition.

6. CONFLICTING PROBLEMS IN THE DEPOSITION OF MARBLING

Even though marbling may be a factor which is related to quality, there are some problems which one should consider before plunging all of his forethought down one narrow channel of logic. The Ohio studies (15) show a significantly negative correlation (-.18**) between marbling and percent lean cuts on 321 pork carcasses. This relationship has been duplicated at Wisconsin in which 29 gilts gave a highly significant and negative correlation of -.66. Barrow comparisons gave negative results but these only approached significance at the 5% level. These observations would agree very nicely with the

positive relationship (previously mentioned) between marbling and fatback and negative association with fatback and lean yield. Even though we must be conscious of quality factors, it would appear illogical to forget about this important relationship. It has required much effort to advance to our present day status with regards to a meatier less wastey pork carcass.

A second factor which is not necessarily a problem but which could become a very serious problem in the future rests with extreme fatty tissue deposition in the muscle. Just this past month, a local packing plant sent a pork loin to the Wisconsin Meat Laboratory; the muscle tissue had been completely replaced with fat.* This picture illustrates the highest marbling score ever recorded. The question arose as to the nature of the fat, and analyses have shown the following:

<u>Fat Sample</u>	<u>Iodine Number</u>		<u>Moisture %</u>
	<u>Fat Loin</u>	<u>Control</u>	
Fatback	58.8	60.0	5.03
(Marbling?) Loin Fat	54.0	53.3	15.27

The above values suggest that the fatty deposition may be marbling rather than fatty tissue such as found in the fatback. If this should be true, then the emphasis on marbling content would certainly need control - if that is possible!

Some workers have suggested that the increase in marbling content should give a greater cooking loss since the hot internal fat would possibly be lost. This is true, as you know, when we consider hamburger, but from results obtained at the Wisconsin station, there is a negative relationship between percent marbling and total cooking loss of pork chops. The values were not significant, but did indicate that increased marbling content would not depress cooking yields. This may be explained from two viewpoints:

1. If the marbling is encased in connective tissue, the liquid state would not flow out unless the walls were severely ruptured.
2. Since a significant percent of cooking loss is due to evaporation as reported by Leverton (22), this would infer that as total moisture content increased, (with a decrease in marbling) then a greater amount of free water would tend to be lost and thus account for a greater total loss.

7. POSSIBLE APPROACHES FOR FUTURE STUDIES OF MARBLING

According to Self (28) and other workers, the blood fat level shows a substantial increase with advanced fattening. This may be one approach in studying marbling deposition or mobilization. It has

been postulated that the blood fat level cannot be regarded as a fat regulator in the body, since the lowering of fat content of the tissue during hunger is the result of mobilization exceeding deposition; however an indirect relationship may exist which could possibly lead to evidences describing the homeostatic nature of body fat in general. Too, similar studies of the lymphatic system possibly could relate important considerations to the phenomenon. Gertner and Bszegedi of Hungary have suggested, through studies on the neuro-hormone mechanism relationship to fat deposition, that there is a definite relationship between body fattening and endocrine balance. Their work has shown a definite rise in ketone content of blood from 1439 mg. % to 2940 mg. % in hogs weighing 50-60 kg. to 350 kg. respectively. A ketone value of 4050 mg. % was found in the blood of a very fat Berkshire pig weighing 400 kg. A ketogenic hormone extract was isolated from the anterior pituitary (source not specified) and injected it into rabbits. This extract increased the blood ketone level of the experimental animals weighing $2\frac{1}{2}$ to 3 kg. by over 200 %. The authors concluded that there was a definite relationship between ketogenic hormone production and fattening ability. This research may be another possible pathway which could lead the researcher to answers concerning marbling deposition.

Finally, it is my thought that more studies in the histology of fat deposition may uncover many facts presently hidden in the mass of complexities. No doubt, the development of practical application of electron microscopy will aid the histologist in his pursuits.

SUMMARY

The material I have presented this morning is undoubtedly far from complete; however, I have attempted to discuss some of the phases which may be important to the meat scientist concerning pork marbling. From the data presented, I would conclude that marbling is related to pork quality. But this is not to say that one should overlook the other factors which may also be associated with quality to a greater or lesser extent. Too, there are difficulties which complicate this conclusion. Perhaps the negative relationship of muscling, and the possible affects of fat on normal livability in man, are factors which should stimulate a certain aura of caution when attempting to improve quality.

*The asterisk throughout this report indicates the use of a slide.

APPENDIX I

STANDARD DEVIATIONS OF CROSS PRODUCTS FOR
CORRELATIONS PRESENTED IN THIS REPORT.

<u>FACTORS</u>	<u>S T A N D A R D D E V I A T I O N S</u>			
	<u>Barrows</u>	<u>Gilts</u>	<u>Misc.</u>	<u>Sows</u>
I. Loin, % Fat (MFB) X	s	s	s	s
A. Miscellaneous				
1. Cooking loss	± .8	± 2.3		
2. Lean yield	± 2.8	± 4.6		
3. Fatback	± 1.0	± 1.1		± .9
4. Lumbar marbling			± .9	
5. Loin marbling	± 3.0	± 3.4		
6. pH			± 1.5	
B. Taste Panel Scores				
1. Flavor	± .9	± 1.7		
2. Tenderness	± 1.2	± 2.2		
3. No. chews	± 5.0	± 7.5		
4. Juiciness	± 1.7	± 2.5		
C. Mechanical				
1. Shear	± 3.2	± 3.2		
2. Grinder	± .22	± .40		
II. Lumbar Marbling X				
A. Loin marbling	± .8	± 1.4	± 2.5	
III. Electrical Resistance X				
A. % Fat, loin			± 23.1	
B. pH			± 3.5	

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CHAIRMAN AUNAN: Thank you, Bob, for your all-inclusive presentation of the pork marbling problem.

Next is Lowell Strong of the U. S. Department of Agriculture on the "Pros and Cons of Grading Wholesale Cuts."

MR. STRONG: Mr. Chairman, thank you, and members of the Conference:

I have been asked to sort of argue with myself up here this morning. I will not discuss too far from my paper here in the interest of catching up towards this lunch hour. The subject seems to me to be considerably broader than just the question of grading wholesale pork cuts.

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