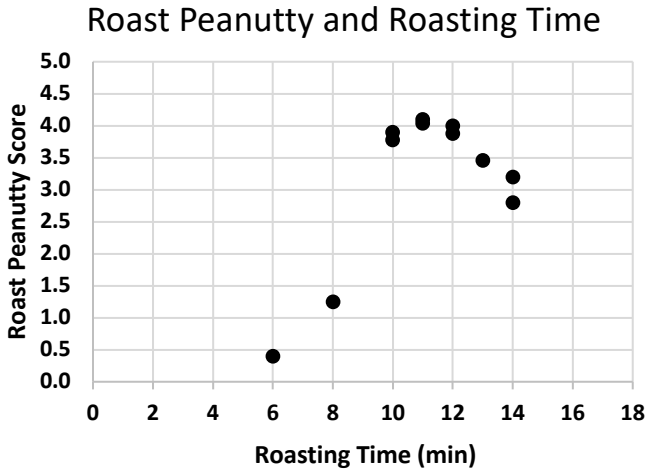
Introduction

The role of MQHRU in this study is to provide a measurement of the peanut flavor in 210 samples provided to us by Dr. Jeffrey Dunne, North Carolina State University Peanut Breeder. The Unit was not provided with the line identities or knowledge of replication within the dataset. To provide the best data for comparison with genetic markers, it is imperative the samples be grown in a well-cared for fashion. The effects of drought and certain insect pests can negatively affect normal flavor formation as well as introduce off-flavors. Upon digging, kernels must be heated and dried carefully to avoid off-flavor formation (e.g. fruity fermented) and over- or under-drying which MAY affect the ability of flavor to fully develop to its potential (MQHRU is working on this). After drying to around 9 to 10 percent, proper storage must happen to avoid formation of other off-flavors (e.g. cardboardy and some bad flavors resulting from insect damage). The final crucial step is roasting.

Roasting

Roasting is accomplished with a variety of devices operated at different temperatures and times. Often, the goal is best roasted peanut flavor but other product characteristics may be paramount such as moisture content or roast colors other than those typically leading to best roasted peanut flavor. Below is a graph (Graph A) of the appearance and disappearance of roasted peanut flavor over a range of roasting times for a variety from the 2015 UPPT. Note that the maximum roast peanutty (RP) scores occur around 11 minutes. Without knowing

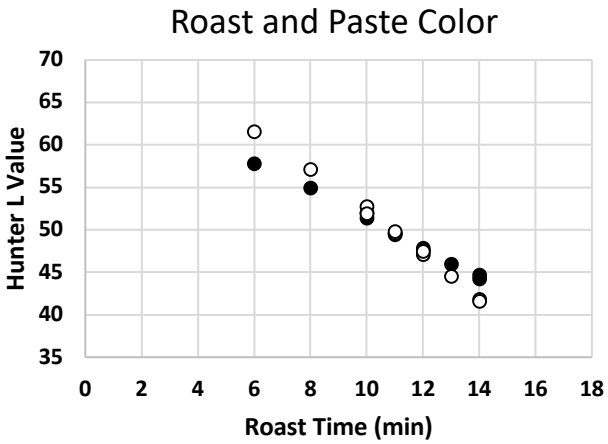


Graph A

such a curve in advance, the roaster may miss this peak value. How is this target reached? Fortunately, there appears to be a relationship between color and flavor in peanuts. Generally, the maximum RP occurs when the Hunter L value is around 49.6 to 50.7. An objective measure of color of peanuts is easily obtained compared to an "objective" estimate of flavor. The best color for roast peanutty flavor has been determined empirically by generations of peanut roasters though the reason this is so has remained unclear. Research in our lab (Lisa Dean, Jack Davis) with objective color estimates and trained sensory panels that help minimize the bias inherent in subjective flavor evaluation is in agreement with generations of empirical observation by roaster operators that the best roast peanutty flavor is achieved by roasting to Hunter L values around 49.6 to 50.7. All varieties tested so far exhibit the pattern in Graph A.

The pattern will shift along the x-axis definitely due to seed size (bigger seed = longer time) and raw moisture content (MC) (higher raw MC = longer time) and perhaps due to other as yet unknown factors. The rate of RP accumulation is similar in all lines and generally crosses the threshold value of 1.0 and reaches maximum RP in 1 to 2 minutes. The drop-off in RP does differ among lines. The rate of drop-off in RP varies somewhat among varieties.

The next graphic (Graph B) shows a plot of the Hunter L value of the roasted nuts compared to the Hunter L value of the paste made from those kernels. It can be seen that the kernel color and paste color lines are different. At low roasting times, the exterior kernel color (solid circles) is lower (darker) than the paste color (white circle) because the interiors of the kernels have not yet experienced high enough temperatures and/or moisture loss for the color reactions to occur. At longer roast times, the interior of the kernels actually becomes darker than the exterior color. The two lines cross at some point. Around 90 %



Graph B

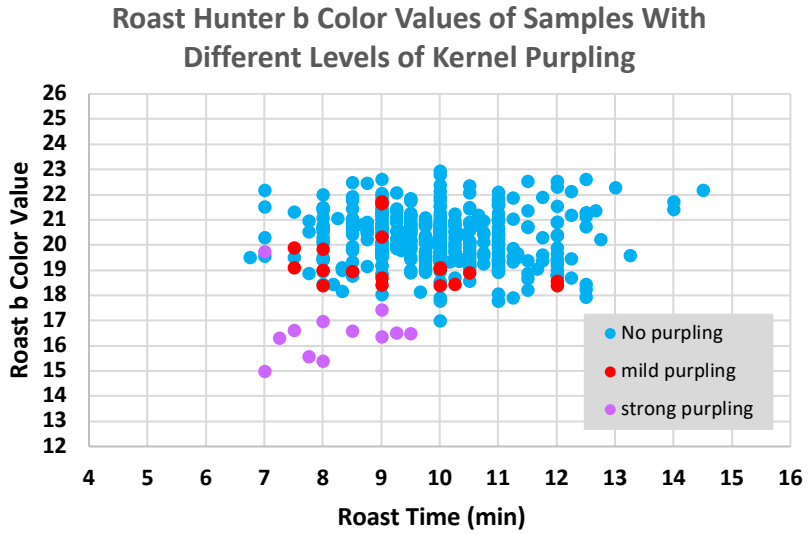
of the time, in the experience of the MQHRU, the time at which these lines cross is also the time that the maximum RP occurs. It would appear that at roasting times lower than this "L-cross" time, flavor formation and accumulation can proceed. After the "L-cross" time, conditions result in a reduction of RP until it is no longer detectable (this point not shown in the above graph). One should remember that the set of lines tested are quite variable in roasting response and, thus, all the data graphed together will not show the above pattern due to shifting along the time-axis. Only a single line will exhibit such clear color kinetics.

These patterns have been observed in hundreds of different samples mostly from the Uniform Peanut Performance Test (UPPT) sample sets. It is possible that some older (release date) or unusual lines may NOT follow this pattern. The bottom line is that even if peanuts are grown and processed well, MQHRU can still fail in evaluations if samples are not roasted to the proper color. This is the only way to properly compare disparate genotypes for their flavor production potential. It is noted that roasting dynamics can alter RP a lot but nothing in the work of the MQHRU thus far explains what the maximum RP will be and why. It is suggested by this and other studies of the Unit that peanut cultivars must be grown, processed and roasted optimally in order to get maximum value out of the DNA work.

Another factor is the effect of maturity. With so many different lines grown in one location, some are doubtless not going to be as mature as others. It is known that immature peanuts have a lower flavor potential but this effect has not been studied using a complete range of roasting times such as outlined

above and combined with extensive compositional measurements. The MQHRU will carry out an experiment in the CY 2020 to test the effect of maturity on the color and flavor development during roasting.

An issue that causes problems with roasting to a color is the purpling of kernel flesh due to extremely dark skin colors. This has been noted in Peanut Germplasm Core samples tested over several years by the Unit. The purpling makes the kernels appear darker than normal. A kernel such as this may have an L value of 50 but will taste like an underdone kernel. This is a problem because it makes it difficult operationally in the roasting plant where it is imperative to use and trust the colors measured. There were several dark-skinned samples in this sample set and roasting them correctly was difficult. Some dark skinned lines showed no purpling of the kernel flesh, however. Purple kernels can be identified in the data by their roast b color values (see Graph C below) and are noted in the data. Apparently the discoloration is mostly on the kernel surface



Graph C

next to the testa as the b value signature does not appear in the paste color values but only the roast kernel colors. If breeding is done with a dark-skinned variety, it will important to avoid this purple condition in the final breeding product.

With the current lot of samples, there was only enough for roasting two reps only. These samples are also extremely variable phenotypically (size, composition). Their condition was poor. Insect and processing induced damaged areas on kernels will roast darker than normal which and will reduce L values out of proportion to the heat treatment applied. The procedure was to make an educated guess on the roast time, roast and measure the resultant color. If the color target was reached on the first roast, the second sample was roasted at the same time to allow for the evaluation of the repeatability of the roaster and the descriptive sensory panel used. If the first roast L value was off target, the time was adjusted and a second attempt was made. In many cases, the second roast missed the mark as well. For this reason, it is important to provide enough sample for four roasts. With four sample replications, MQHRU can almost guarantee reaching the proper color (more is always better).

Protocol

Samples were riffle divided into two 90 g samples. Oil content was non-destructively measured with NMR. Samples were then frozen until the day before roasting. After samples were equilibrated to lab temperature and immediately prior to roasting, samples were taken for raw moisture content (MC). Roast time was estimated and the kernels roasted. Roast color was measured with a Hunter Colorimeter and samples taken for roast MC. The sample was then pasted and frozen until sensory evaluation which occurred within 5 days of pasting.

Results

All 420 samples (2 x 210) were roasted and pasted and tasted. The scores are lower than expected and would probably have been higher with better controlled storage after harvest. Many of the samples were visibly in poor condition, i.e. damaged either by insects or processing. Some appeared shrunken in appearance which was interpreted as possible immaturity. Immature seeds are wetter and thus may be prone to wrinkles upon drying compared to mature kernels from the same lot. This was enhanced by the fact that MCs ranged in the 4.5 to 5.5 percent range which may be somewhat too dry. It is difficult to know with certainty if the relative rankings of the lines would be the same if the kernels were in better condition or if the maturity state were known. Photographs were taken of each sample in the raw state for reference and are available if needed.

An Excel file with the data summary is provided as a separate document. As stated earlier, not all roast targets were met, therefore the sensory file was sorted into 7 sections based on roast Hunter L color. These ranges are shown below:

Group 1	**L values < 48.0**	**over-roast, least reliable**	**N = 28**
Group 2	**48.0 to 49.0**	**less reliable**	**N = 26**
Group 3	**49.0 to 49.6**	**less reliable**	**N = 30**
Group 4	**49.6 to 50.7**	**most reliable**	**N = 69**
Group 5	**50.7 to 51.6**	**less reliable**	**N = 17**
Group 6	**51.6 to 52.5**	**less reliable**	**N = 20**
Group 7	**L Values > 52.5**	**under-roast, least reliable**	**N = 20**
Total			**N=210**

Off-target samples may be unreliable compared to those in the color target range, but these samples also have an upside because they could be expected to have higher scores if they were the “correct” color. Thus, attention is directed to high-RP scores (> 4) in these groups (1-3, 5-7). An “unreliable sample” means that the sample flavor measured cannot be taken “as is” as an estimate of the maximum flavor possible in a particular line (for a given line in given location in given year). Table A below shows some of the mean color and flavor characteristics of the lines in each color group.

Table A.

Color Group	Count	Mean Oil (% WW)	Mean raw MC (% DW)	Mean roast MC (% DW)	Roast L	Roast a	Roast b	Paste L	Paste a	Paste b
1	28	50.45	5.16	1.20	46.60	7.13	18.81	46.32	8.44	21.50
2	26	50.92	5.16	1.24	48.58	7.70	19.60	47.77	8.59	22.15
3	30	51.10	4.96	1.27	49.33	7.30	19.98	48.73	8.14	22.54
4	69	50.69	5.20	1.19	50.08	7.18	20.35	50.01	7.42	22.96
5	17	51.52	5.25	1.04	51.09	6.99	20.77	50.72	7.49	22.86
6	20	51.07	5.14	1.06	52.07	6.57	20.81	52.16	6.58	23.13
7	20	51.27	5.38	1.05	54.11	5.57	21.52	54.07	5.07	23.36

Table A. (continued)

Color Sorter	Count	Mean RP	Mean SA	Mean DR	Mean RB	Mean Sweet	Mean Bitter	Mean Ashy
1	28	3.67	3.09	3.29	1.69	2.98	2.56	0.68
2	26	3.87	3.19	3.23	1.75	3.03	2.59	0.48
3	30	3.84	3.14	3.22	1.83	3.14	2.56	0.49
4	69	3.83	3.15	3.15	1.86	3.02	2.51	0.41
5	17	3.71	3.06	3.14	1.94	2.81	2.53	0.39
6	20	3.78	3.03	2.96	2.07	3.00	2.40	0.12
7	20	3.44	2.85	2.78	2.28	2.93	2.41	0.19

The Excel file we have produced was structured following steps below:

1. To carry out all measurements and provide a list of data for all roast replicates. Notes on condition were made during testing including a visual estimate of purpling. For each pair of replicates for each line, the rep with the highest RP score (Hi-Rep) was marked by an "x".

   The entire dataset, sorted by MQHRU Sample Number, is provided in Worksheet 1 which is titled "1 Data Sort by MQHRU Code". Worksheet 2, titled "2 Data Sort by Color Group" is the same data as in Worksheet 1 but sorted by Color Group. Worksheet 3, titled "3 Data Sort by Purpling" is the same data sorted by the purpling condition. Graph C was created from Worksheet 3. Worksheet 4, titled "4 Data Sort by Hi Rep-Color Grp" is the same data sorted by Hi-Rep and then Color Group within Hi-Rep. Worksheet 5, titled "5 Hi-Reps Sort by MQHRU Code" contains only the high RP rep and sorted by MQHRU code. Worksheet 6, titled "6 Hi Reps Sort by Color Group" contains only the high RP rep sorted by color group. Table A was produced from the data in Worksheet 6.

2. Accept Group 4 means (N=69) as is. Realizing than means in the other groups around Group 4 were underestimates by 0 to 2 flavor units), then keep any high rep RP score above 3.9 (arbitrary). Worksheet 7, titled "7 On-Target + Other Hi RP Lines", contains the results of

applying these rules. The dataset of 210 high reps is sorted by the column “keeper” into 3 groups of samples: “on-target”, “keepers” (saved off-target scores over 3.9), and “no” (off-target scores less than 3.9).

Using this approach, 69 of 210 estimates were “on-target” color, 55 were “keepers” (off-target but with RP >3.9) and 86 were off-target but with RP less than 3.9.