Development of Distasteful Flavor in Beer

This experiment was made to discover (a) whether somewhat inexperienced beer-drinkers could rate the taste of beer in a scientifically useful way (b) whether beer exposed to light could be detected by them (c) how much exposure was needed (d) whether different sorts of bottles made a difference to the beer.

Experimental Material. The Duquesne Brewery shipped to us, in a light-tight carton, 24 bottles of beer processed together, in 12 oz. steinies. Eight bottles were amber; eight were Emerald Green; and eight were flint. The spectral transmission has not, as yet, been determined either in the visible or in the ranges outside the visible.

Out of these 24 bottles we selected 9, at random, for this test: three amber, three Emerald Green, three flint. They were of various manufacturers, as described later.

Tasters. Seven members of the Lab staff were the guinea pigs: six were men, and one a woman. Their ages varied from the late twenties to early seventies. Their intelligence was above average, but their knowledge of beer probably below average. Four were university graduates, and the others probably had equally good IQ's. They were all conscientious and there was no cheating.

Preparation of Beer. We stored the beer, as received, out of doors, in the shade, in its light-tight case; the air temperature (shade temperature) was 50°F. They were thus stored till 11 a.m., E.W.T.

Shortly after 11 a.m., a green, an amber, and a flint bottle were exposed to the sunlight for one minute, in the open air, on the concrete drive in front of the Lab. Another set of three, a green, an amber, and a flint, were exposed similarly for twenty minutes. This was on October 30, 1944; air temperature as before mentioned 50°F; wind west, fair breeze, extending our flag fairly horizontally on its mast. Bright sunshine: sky cloudless: visibility about three miles.

After exposure, the bottles were returned to their light-tight case, still stored out of doors in the shade, to cool off as much as practicable, till 12:05 p.m. eastern war time. All nine bottles were then brought into the testing department and stood upon a table, screened from the guinea-pigs, and in a somewhat subdued light.

Eighty-four Coca-Cola type tumblers, freshly washed, also stood on this table. The seven tasters sat behind the screen, and were served beer by two "barmaids", (two other members of the staff), from the table. Each taster had just a small mouthful to taste, and did not swallow it. As soon as he (or she) thought he could rate it as tasting good (A), bad (C), or indifferent (B), he spat it out into the sink, and recorded his rating secretly in a book. No comments were allowed, and each taster had his own individual book.

The order in which the bottles were opened and served was "shuffled" considerably, so that no one had any idea what was coming. Moreover three bottles were used twice, making twelve tests from nine bottles. (See Tabulation). The second set of seven glasses was poured while the first was being tasted, and so on, so that all samples had about equal time to lose carbonation. The temperature of the beer remaining in each bottle was measured immediately after the tumblers were supplied. They varied from 52.5°F to 59.0°F. The flint "tastes" averaged 54.5°F; the emerald green 55.6°F; the amber 56.4°F. Thus the beer from the amber containers was slightly the hottest, and the flint slightly the coldest.

There were four "tastes" of unexposed beer, average temperature 53.7°F; three "tastes" of beer exposed for one minute, average temperature 54.3°F (less than a degree hotter than unexposed beer); and five "tastes" of beer exposed for twenty minutes, average temperature 58°F.

Ratings Obtained. Table I gives the results obtained from the various observers; gives also the color of the bottles, the manufacturer thereof, and two composite ratings, and the temperature at the time of tasting.

TABLE I

Beer-tasting Experiment, 10/30/44

Observer	No Exposure				1-Minute Exposure			20-Minute Exposure				
	Amber	Flint	Green		Amber	Flint	Green	Amber		Flint	Green	
	1	2	3	8	10	9	4	6	12	7	5	11
	Reed	Knox	Glenshaw		O-I	Glenshaw	Glenshaw	O-I		Glenshaw	Glenshaw	
Ghering	A	A	A	A	A	B	B (Skunky)	B	A	C	C	C
Wiest	A	B	B	A	B	B	C	A	B	C	C	C
Basham	A	A	B	A	A	B	C	A	A	C	C	C
Ferguson	A	C	B	A	B	B	C	A	A	C	C!	C!
Renno	A	B	B	A	B	B	C	B	A	C	C	C
Scholtz	A	A	A	A	A	C	C	A	C	C	C	C
Knight	A	A	A-	A	A+	B	B (Strong)	B-	A	C	C!	C
Points	+7	+3	+3	+7	+4	-1	-5	+4	+4	-7	-7	-7
Median	A	A	B	A	A	B	C	A	A	C	C	C
Temp.	54.0°	52.5°	53.5°	54.0°	55.0°	54.0°	54.0°	57.5°	59.0°	57.0°	58.0°	58.5°

D Discussion of Ratings. The composite rating, (last line but two), is obtained by adding all the individual ratings above it, setting A = +1 = good; B = 0 = indifferent; C = -1 = poor or bad. On this basis there can be no ratings lower than -7 or higher than +7. But the exclamation marks behind some of the C's indicate that two observers would rate them still lower if they were allowed. Note that these exclamation marks are all upon green bottles, none upon flint.

The most important thing is that everyone without the slightest exception heartily disapproves of beer exposed to sunlight for twenty minutes, rating it C or worse. They do not disapprove of beer exposed for twenty minutes in amber, giving it an "A" rating. Their disapproval is not due to the beer being warmed by exposure, for the amber bottle got as hot as the others.

The next significant point is, that high ratings are given to unexposed beer, showing that the observers can generally detect it, but they are not so consistent on "good" beer as on "bad". It is clear you cannot depend on a single observer where "good" beer is concerned: Ferguson missed the boat completely on the unexposed flint, and more than half the observers were undecided between A and B ratings for the green bottle (unexposed). On test 8 (the recheck), everybody gave it an A rating, because they had just carried out test 7, which was universally rated bad.

This leads us to conclude that a difference of four points in the composite rating is not significant, and may be the result of what was tested just before. We may therefore assume that it is fairly objective to say that a plus rating implies palatable beer; and a negative rating means unpalatable, while a zero value or a value near zero can be accounted neutral.

It is fairly clear that though individual observers are not by any means infallible, their idiosyncrasies are largely eliminated in the composite score.

In some ways the most interesting thing of all is the scoring at one minute exposure. This is a very brief exposure, the temperature rise of the contents is scarcely more than half a Fahrenheit degree, but the composite score shows that while the amber is unaffected, the flint is already "indifferent" while the emerald green is definitely "poor". Further exposure makes both flint and emerald green unequivocally "bad", while the amber still remains completely unaffected. As things stand this would suggest that green is a worse container than flint; but the difference of rating is only four points, which seems to be borderline, and may not be significant, as is the case with unexposed beer. This we shall deal with later. However the difference between flint and green together on the one hand and amber on the other is definitely significant, and this was achieved in one minute on a wintry late-October day.

I therefore see no reason to doubt Mr. L. Koenig's statement that in hot summer weather a walk of 80 ft., occupying perhaps twelve or fifteen seconds, is enough to affect the taste of beer carried in the hand.

It seems to me unlikely that so quick a reaction can be biological, and a rise of 1/2°F is not enough to account for chemical action proper. Therefore it seems Wahl-Henius must be right in calling it photo-chemical, and Duquesne is right in ascribing it to the action of light as such.

Our first questions are therefore answered. Duquesne supplied us with beer which was initially quite similar in all bottles, as rated by our tasters. Exposure to light in O-I amber bottles produces very little effect, though the Koenig's say they can detect it at times. Exposure in emerald green or flint bottles is disastrous. The phenomenon is genuine, and there now remain two questions:--

(a) what is the reaction?

(b) can it be prevented by means other than using dark amber bottles?

This of course involves a subsidiary question, of great practical importance to Duquesne,

(c) are all amber bottles satisfactory, so long as they are "amber"?

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The first question, ("what is the reaction?") belongs to the field of beer technology proper and cannot be dealt with here. Wahl-Henius assert it is the formation of volatile mercaptans, but by their method of testing with methylene blue, it takes days or weeks of exposure to produce measurable mercaptans, whereas by tasting the unpalatableness is obvious in one minute of even winter sunshine. Esselen and his co-workers, dealing with fruit juices, insist that these other liquids are rendered unpalatable mainly by oxidation.

The second question can be answered promptly. It is only reasonable to suspect from general considerations, and also from the results of Table I, which hints that flint (colorless) glass is at least equal to emerald green, that the real culprint is ultra-violet light; that you can have any color of glass you like, provided you have a glass that completely cuts out the ultraviolet.

Glass, containing a little iron oxide in the "oxidised" form, will cut out considerable ultraviolet, while transmitting infrared pretty well. If made under "reducing" conditions in the furnace, the flint will transmit much more ultraviolet and much less infrared. Emerald green is made under reducing conditions and passes substantial amounts of ultraviolet. At wave length 3650Å (a mercury arc line) a sample of emerald green we had here, 1/8" thick, passed 40%, while a similar sample of amber passed none. The amber is made under reducing conditions, but none the less cuts out the ultraviolet.

However all ambers are not perfectly effective in cutting out ultraviolet, flint glasses vary considerably, and so do emerald greens. We find this at 3650 Angstroms, and Sharp has proved it over a longer range of ultra-violet wave lengths. We may expect that still shorter wave lengths than 3650 will be even more effective: such wave-lengths are present in sunlight, and so glasses may not rate in perfectly correct order when tested, as it is convenient for us to do, at 3650A.

Cellophane, perfectly colorless, is quite good at cutting out ultraviolet, in spite of the fact that it is so thin. Six layers of cellophane cut out ultraviolet at 3650 completely.

A flint glass about 1/4" thick--the body portion of a siphon bottle in fact--cuts out considerably more ultraviolet than a 1/8" piece of emerald green; and the siphon wall plus a double layer of cellophane cuts it out completely.

We therefore made this experiment. Three bottles of Duquesne's consignment, all emerald green, were used: one was unexposed: one was exposed for twenty-five minutes to sunshine on October 31: (wind south, air temperature approximately 62°, sky cloudless): the third was wrapped in colorless cellophane, placed under the colorless siphon bottle body, for twenty-five minutes in the sunshine. The unexposed bottle was called #3, the cellophane-wrapped one #2, and the unprotected, exposed, one #1.

The tasters made the experiment as before, and their ratings are given in Table II, each bottle being sampled three times, unknown to the guinea pigs, in the order listed at the top.

TABLE II

Trial	1	5	8	2	6	7	3	4	9
Treatment	Unex.	Unex.	Unex.	prot.	prot.	prot.	exp.*	exp.*	exp.*
Bottle	3	3	3	2	2	2	1	1	1
Temperature	52.0°	54.0°	55.0°	64.0°	64.5°	64.5°	65.5°	66.0°	66.5°
Ghering	A	A	A	A	A	A	C	C	C
Wiest	A	A	A	A	A	A	C	C	C
Basham	A	A	A	A	B	A	C	C	C
Ferguson	B	A	B	B	B	A	C!	C	C!
Renno	A	A	A	B	B	A	C	C	C
Scholtz	A	A	A	A	A	A	C	C	C
Knight	A	A	B	B	B	A-	C	C	C
A = +1, B = 0, C = -1	+18			+14			-21		

* time of exposure 25 minutes to direct sunlight.

Comments on the findings. The tasters are not fooled in the slightest. A plus rating means good beer, and there is no significant difference between unexposed beer and beer exposed in cellophane. This is in spite of the fact that one is ten or twelve degrees hotter than the other. The bottle exposed without protection is unaminously rated "bad" to "vile" (C!). Its temperature is substantially the same as the cellophane-wrapped one, so it is not a matter of temperature. Neither is it a matter of color--the two bottles are alike. It is a matter of protection from ultraviolet.

This is totally at variance with the Wahl-Henius view that it is a matter of protection from green light.

It follows that if we can find an ingredient for the glass which cuts out all the ultraviolet (as cellophane in much less thickness does), then the glass can be blue, green, brown, or red indifferently, or completely colorless like the cellophane.

Or, if we wrap the bottles in cellophane, we get over most of our troubles, but are involved in some trouble and expense. Or we can get to the bottom of things, and find out what reaction it is that is catalysed by the ultraviolet, and remove one or more of the reactants.

Various other things follow, which I need not here dwell upon.

The immediate problem that concerns Glenshaw, which falls within the field of glass technology, is whether a suitable glass ingredient can be found that, when added to emerald green glass, leaves it emerald-colored in the visible spectrum but cuts out the ultraviolet which at present passes. This we hope to deal with in a separate report.

F. W. Preston

dmg

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