THE EFFECT OF FUNGI ON THE FLAVOR AND COLOR OF TOMATO JUICE

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INTRODUCTION

Many organisms impart a characteristic off flavor to various food products. L. B. Jensen (1) has classified bacteria causing musty flavors on different food products. He states they have never observed molds as the causative agents of true mustiness in foods.

Mold counts are officially employed to determine adulterations in many food products. As commonly used they are also assumed to indicate the general sanitary conditions of the plant. High mold counts would indicate unsatisfactory sanitation. More should be known about the actual effects of microorganisms on the quality of the products.

The effects of fungi and yeast on the flavor of tomato juice were studied to determine whether the use of a highly infected raw product would produce noticeable differences in the flavor of the canned juice.

Some of the organisms were grown with reduced oxygen supply to approximate conditions encountered in commercial canning.

METHODS

Twenty-eight molds and yeasts (see Table I) were obtained from Dr. M. D. Heise[1] and Dr. W. D. Gray.[2] All the available tomato pathogens were selected including *Rhizopus nigricans*, *Rhizoctonia* sp., *Fusarium* sp., *Colletotrichum* sp., and *Alternaria* sp. The remaining organisms were chosen as possible contaminating agents from the air.

One hundred ml. of a commercial brand of Ohio tomato juice were pipetted into 250 and 125 ml. Erlenmeyer flasks. The flasks and juice were autoclaved for 15 minutes at 10 lbs. pressure. The smaller flasks were used to determine the effect of a reduced oxygen content on the growth since after the addition of the juice to the flask an air space of one-half inch remained, leaving only a small surface area exposed to the atmosphere. The juice was inoculated with the organisms and the tests and uninoculated controls run in triplicate. The samples were incubated at room temperature. After a week of incubation, 10 ml. of the juice from each flask were removed and autoclaved. An Abbé refractometer reading was made, pH determined by a Beckman potentiometer, and the flavor, odor and color of each sample were recorded. The flasks were incubated for a total of five weeks and the determinations made weekly.

RESULTS

The results of weekly determination of pH, refractive indices and the final odor, flavor and color are recorded in Table I. The organisms in the 250 ml. flask produced a greater growth with greater changes in pH, refractive indices, color, odor and flavor than those grown in the 125 ml. flasks. The rate of the physiological changes was greatly decreased in the smaller flasks. With the weekly removal of 10 ml. of the juice, larger surface areas were exposed so that by the fourth and fifth week the difference in growth in the small vs. large flasks was less pronounced.

[1]Bacteriology Department, Ohio State University.
[2]Botany Department, Ohio State University.

TABLE I

EFFECT OF 28 MICROORGANISMS ON pH, REFRACTIVE INDICES, COLOR, TASTE AND ODOR OF TOMATO JUICE

ORGANISM	pH					REFRACTOMETER READING					COLOR	TASTE	ODOR
	1st Week	2nd Week	3rd Week	4th Week	5th Week	1st Week	2nd Week	3rd Week	4th Week	5th Week	5th Week	5th Week	5th Week
Control (not inoculated)	4.28	4.26	4.29	4.28	4.28	1.3412	1.3436	1.3439	1.3430	1.3411	Tomato	Normal	Normal
Alternaria sp. (1)*	4.24	4.10	3.83	4.76	6.41	1.3427	1.3414	1.3393	1.3358	1.3362	Black	Musty	Musty
Alternaria sp. (2)**	4.30	4.18	4.28	4.26	4.40	1.3429	1.3430	1.3443	1.3415	1.3372	Tomato	Normal	Normal
Aspergillus niger 1	4.04	4.94	5.60	6.74	6.55	1.3401	1.3352	1.3351	1.3345	1.3336	Dark Brown	Musty	Musty
Aspergillus niger 2	4.17	4.20	4.58	4.78	6.98	1.3416	1.3404	1.3398	1.3376	1.3361	Light Brown	Musty	Musty
Aspergillus herbariorum 1	4.13	4.23	7.36	7.86	9.08	1.3418	1.3720	1.3365	1.3341	1.3342	Dark Brown	Bitter	Pungent
Aspergillus herbariorum 2	4.30	4.22	4.22	4.26	4.37	1.3421	1.3422	1.3365	1.3378	1.3359	Tomato	Normal	Normal
Beauveria sp. 1	4.09	4.75	8.42	8.72	8.80	1.3383	1.3374	1.3358	1.3379	1.3362	Orange	Flat	Musty
Beauveria sp. 2	4.20	4.22	4.44	4.44	4.79	1.3401	1.3399	1.3398	1.3392	1.3380	Tomato	Flat	Musty
Cephalosporium sp. 1	4.15	8.01	8.87	9.04	9.11	1.3385	1.3327	1.3350	1.3348	1.3348	Brick Red	Flat	Flat
Cephalosporium sp. 2	4.21	4.23	4.42	4.88	5.39	1.3424	1.3413	1.3395	1.3387	1.3362	Brick Red	Flat	Flat
Choanephora sp. 1	4.13	8.87	9.06	8.96	8.99	1.3370	1.3359	1.3355	1.3352	1.3358	Brick Red	Bitter	Pungent
Choanephora sp. 2	4.20	4.24	4.46	4.70	4.88	1.3421	1.3416	1.3393	1.3398	1.3384	Red	Bitter	Pungent
Colletotrichum sp. 1	4.27	8.99	9.09	8.98	9.44	1.3411	1.3377	1.3350	1.3355	1.3362	Brown Orange	Musty	Pungent
Colletotrichum sp. 2	4.21	4.82	4.93	5.20	5.86	1.3421	1.3418	1.3399	1.3392	1.3387	Orange	Musty	Normal
Debaromyces lactis sp. 1	4.06	4.28	7.80	8.36	8.90	1.3383	1.3370	1.3354	1.3358	1.3365	Brown	Bitter	Pungent
Debaromyces lactis sp. 2	4.17	4.21	4.18	4.24	5.23	1.3423	1.3420	1.3420	1.3396	1.3372	Tomato	Bitter	Normal
Diplosporium sp. 1	4.33	4.28	4.66	8.86	9.53	1.3415	1.3409	1.3489	1.3358	1.3357	Brown	Flat	Pungent
Diplosporium sp. 2	4.22	4.11	4.23	4.23	7.32	1.3443	1.3443	1.3448	1.3420	1.3380	Tomato	Bitter	Normal
Eurotium sp. 1	4.27	4.70	8.42	9.03	8.83	1.3402	1.3358	1.3354	1.3350	1.3363	Light Brown	Bitter	Pungent
Eurotium sp. 2	4.27	4.31	4.46	4.92	6.28	1.3422	1.3417	1.3396	1.3393	1.3382	Tomato	Bitter	Normal
Fusarium sp. 1	4.23	4.29	5.22	6.81	9.40	1.3402	1.3389	1.3364	1.3365	1.3362	Orange Brown	Flat	Pungent
Fusarium sp. 2	4.24	4.16	4.23	4.45	8.91	1.3422	1.3420	1.3418	1.3373	1.3380	Tomato	Sour	Sour

TABLE I—(*Continued*)

Organism	pH					Refractometer Reading					Color	Taste	Odor
	1st Week	2nd Week	3rd Week	4th Week	5th Week	1st Week	2nd Week	3rd Week	4th Week	5th Week	5th Week	5th Week	5th Week
Myrothecium sp.	4.27	4.21	4.27	6.12	7.06	1.3422	1.3418	1.3420	1.3364	1.3358	Tomato	Bitter	Sour
Myrothecium sp.	4.28	4.96	5.22	5.41	5.44	1.3423	1.3421	1.3412	1.3396	1.3372	Tomato	Bitter	Normal
Monilia sp. 1	4.37	5.40	8.92	9.15	9.58	.....	1.3376	1.3374	1.3371	1.3373	Dark Brown	Flat	Pungent
Monilia sp. 2	4.26	4.37	4.67	4.73	5.62	1.3421	1.3404	1.3381	1.3381	1.3379	Tomato	Flat	Pungent
Mucor sp. 1	4.29	4.12	5.54	6.08	8.53	1.3382	1.3372	1.3364	1.3361	1.3370	Orange	Sour	Sour
Mucor sp. 2	4.28	4.37	4.94	5.81	6.97	1.3342	1.3396	1.3392	1.3384	1.3386	Tomato	Sour	Sour
Paecilomyces sp. 1	4.17	4.18	6.32	7.17	6.83	1.3382	1.3365	1.3351	1.3360	1.3370	Dark Brown	Musty	Musty
Paecilomyces sp. 2	4.24	4.21	4.43	4.97	5.02	1.3441	1.3403	1.3395	1.3387	1.3373	Dark Brown	Musty	Musty
Penicillium sp. 1	4.53	6.75	7.46	7.58	8.11	1.3386	1.3358	1.3370	1.3368	1.3379	Tomato	Flat	Off
Penicillium sp. 2	4.23	4.67	4.98	5.75	6.02	1.3408	1.3398	1.3372	1.3379	1.3378	Bright Red	Flat	Off
Pichia sp. 1	4.21	4.31	4.98	6.64	7.76	1.3387	1.3371	1.3365	1.3363	1.3370	Orange	Sour	Sour
Pichia sp. 2	4.18	4.20	4.55	5.76	7.31	1.3393	1.3399	1.3382	1.3380	1.3376	Orange	Sour	Sour
Rhizoctonia sp. 1	5.10	5.96	6.98	7.44	8.09	1.3392	1.3384	1.3360	1.3353	1.3361	Dark Red	Bitter	Off
Rhizoctonia sp. 2	4.26	4.24	4.38	5.12	6.95	1.3398	1.3392	1.3385	1.3385	1.3371	Dark Red	Bitter	Off
Rhizopus nigricans 1	4.70	5.21	5.94	6.72	7.33	1.3398	1.3382	1.3377	1.3378	1.3367	Dark Brown	Sour	Sour
Rhizopus nigricans 2	4.30	4.29	4.36	4.3	4.92	1.3396	1.3402	1.3390	1.3387	1.3381	Light Brown	Sour	Sour
Saccharomyces nadsoni 1	4.93	5.21	5.78	7.25	7.62	1.3382	1.3374	1.3360	1.3370	1.3362	Tomato	Sour	Yeast
Saccharomyces nadsoni 2	4.26	4.22	4.91	5.83	7.04	1.3406	1.3396	1.3381	1.3387	1.3370	Tomato	Sour	Yeast
Schizosaccharomyces sp. 1	4.24	4.22	4.23	4.02	5.95	1.3426	1.3422	1.3430	1.3430	1.3419	Tomato	Sour	Yeasty
Schizosaccharomyces sp. 2	4.21	4.18	4.33	4.87	4.82	1.3421	1.3423	1.3428	1.3430	1.3430	Tomato	Sour	Yeasty
Schizosaccharomyces octosporus 1	4.20	4.33	4.31	4.33	4.96	1.3433	1.3419	1.3391	1.3378	1.3373	Light Tomato	Sour	Yeasty
Schizosaccharomyces octosporus 2	4.22	4.20	4.38	4.56	4.54	1.3421	1.3426	1.3433	1.3431	1.3428	Light Tomato	Sour	Yeasty
Scopulariopsis sp. 1	4.25	7.85	9.02	9.04	9.46	1.3375	1.3370	1.3355	1.3357	1.3366	Dark Brown	Bitter	Musty
Scopulariopsis sp. 2	4.20	4.22	4.25	4.47	8.43	1.3440	1.3444	1.3430	1.3399	1.3382	Tomato	Normal	Normal

TABLE I—(*Continued*)

Organism	pH					Refractometer Reading					Color	Taste	Odor
	1st Week	2nd Week	3rd Week	4th Week	5th Week	1st Week	2nd Week	3rd Week	4th Week	5th Week	5th Week	5th Week	5th Week
Syncephalastrum cinereum 1	4.18	4.07	4.74	4.61	9.04	1.3412	1.3360	1.3389	1.3370	1.3354	Light Brown	Flat	Off
Syncephalastrum cinereum 2	4.16	4.13	4.24	4.27	4.31	1.3442	1.3435	1.3425	1.3450	1.3386	Tomato	Normal	Normal
Torula sp. 1	4.68	5.24	5.93	6.76	7.41	1.3393	1.3384	1.3375	1.3378	1.3372	Deep Red	Sour	Yeasty
Torula sp. 2	4.03	4.18	4.65	4.98	5.74	1.3407	1.3398	1.3399	1.3391	1.3386	Tomato	Sour	Yeasty
Trichoderma sp. 1	4.21	4.59	8.44	8.84	9.04	1.3409	1.3394	1.3364	1.3360	1.3364	Dark Brown	Flat	Off
Trichoderma sp. 2	4.33	4.24	4.42	7.32	7.69	1.3452	1.3432	1.3409	1.3390	1.3368	Dark Brown	Slight Sour	Sour
Verticillium sp. 1	5.06	5.45	7.32	8.44	9.60	1.3379	1.3381	1.3366	1.3373	1.3366	Dark Brown	Sour	Musty
Verticillium sp. 2	4.17	4.28	4.56	5.32	5.95	1.3424	1.3413	1.3398	1.3382	1.3385	Brown	Sour	Musty
Hansenula sp. 1	5.03	5.42	5.87	6.12	6.99	1.3426	1.3389	1.3372	1.3362	1.3360	Lt. Tomato	Sour	Yeasty
Hansenula sp. 2	4.19	4.68	4.97	5.62	5.73	1.3442	1.3438	1.3410	1.3391	1.3389	Tomato	Sour	Yeasty

*100 ml. juice in 250 ml. flask.
**100 ml. juice in 125 ml. flask (reduced oxygen content).

In the 250 ml. flasks an increase in pH was accompanied by a decrease in the refractometer readings indicating a decrease in total solids content. Those organisms producing the most pronounced pH changes included *Aspergillus herbariorum, Choanephora* sp., *Colletotrichum* sp., *Diplosporium* sp., *Fusarium* sp., *Scopulariopus* sp., *Trichoderma* sp., *Verticillium* sp., *Cephalosporium* sp. and *Monilia* sp. The pH of these organisms at the end of the fifth week was over nine. The organisms giving the greatest decrease in refractometer readings were *Aspergillus niger, Aspergillus herbarorium, Cephalosporium* sp. and *Syncephalastrum cinereum.*

As incubation progressed color changes became more marked. The fungi at the end of the fifth week produced colors ranging from an orange to a brick red to a dark brown. Most of the yeasts produced an orange white color. A change in color was accompanied with the production of off tastes and odors. At the end of the first week no off odors or flavors were detected in the flasks containing fungi (Table I).

Data on each organism was recorded as given in Table II. This table shows the early change in color, taste and odor produced by *Aspergillus niger.*

TABLE II

THE EFFECT OF *Aspergillus niger* ON pH REFRACTIVE INDICES, COLOR, TASTE AND ODOR

Organism	No. of Weeks	pH	Refractometer Reading	Color	Taste	Odor
Aspergillus niger	1	4.04	1.3401	Normal	Normal	Normal
	2	4.94	1.3352	Dark Brown	Musty	Musty
	3	5.60	1.3351	" "	"	"
	4	6.74	1.3345	" "	"	"
	5	6.55	1.3336	" "	"	"
Reduced oxygen content	1	4.17	1.3416	Normal	Normal	Normal
	2	4.20	1.3404	"	"	"
	3	4.58	1.3398	"	"	"
	4	4.78	1.3376	"	"	"
	5	6.98	1.3361	Light brown	Musty	Musty

CONCLUSIONS

1. pH values increased progressively with the length of incubation.
2. As the pH values resulting from mold growth increased, the refractive indices decreased.
3. Color changes occurred after the first week ranging from orange to brick red to dark brown.
4. In most samples of moldy product off flavors and odors were produced between the second and third week. Yeast produced sour flavors and yeasty odors within the first week of incubation.
5. Since the development of molds depends in part upon an adequate supply of oxygen, it is obvious that commercial canners need not be concerned about the development of off flavors from these organisms after the product is effectively canned or bottled. On the other hand, it is possible that off flavors can be developed from molds growing on tomato fruits or the crushed product prior to the sterilization and inclosure in receptacles which greatly limit the supply of oxygen. This contamination can occur in the farmers' fields, at the cannery yard, receiving station, on conveyor belts, pumps and other plant equipment.

REFERENCES

(1) **L. B. Jensen.** Mustiness in Foods. Food Res., Vol. 13: 89–93, April, 1948.