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SECTION 5.1

FOOD & AGRICULTURE
WINE FERMENTATION

(Updated September 2004)

EMISSION INVENTORY SOURCE CATEGORY
Industrial and Other Processes

EMISSION INVENTORY CODES (CES CODES) AND DESCRIPTION
420-408-6090-0000 (47068) Wine Fermentation

METHODS AND SOURCES

This category is an inventory of the ethanol emissions resulting from the fermentation of grape juice at wineries to produce wine.

During the fermentation process, sugar in the grape juice reacts with yeast to form alcohol (ethanol) and carbon dioxide (CO_2) gas. Ethanol is emitted into the atmosphere through evaporation. According to Williams and Boulton[1], the only important mechanism for ethanol loss is equilibrium evaporation into the escaping CO_2 stream. The physical entrainment of ethanol droplets in the CO_2 gas is insignificant in modern enclosed fermentation vessels.

Wine fermentation in California was reported by the U.S. Alcohol and Tobacco Tax and Trade Bureau (TTB) to be 1,060,652,476 gallons in 2002. Monthly fermentation data was reported on a county basis by year upon request from ARB staff.

The Department of Alcoholic Beverage Control[2] (DABC) permits the wine production activities at each winery in the state, limiting them to a maximum amount of wine produced each year. This data is aggregated and reported at the air basin and county level (Table I). The amount of wine annually fermented in each county, air basin, and district (COABDIS) region was disaggregated using this DABC data by apportioning the 2002 county total according to the permitted maximum amount of wine each COABDIS region can produced.

The emission factors used in estimating ethanol emissions during wine fermentation are as follows: white wine - 2.5 lbs. ethanol/1000 gallons wine and red wine - 6.2 lbs. ethanol/1000 gallons wine produced. The Air Resources Board staff[3] derived the emission factors from a computer model developed by Williams and Boulton[1]. The model simulates the effects of fermentation temperature and the sugar concentration in the fermenting juice on the amount of evaporative ethanol loss during isothermal batch fermentation. Results show that the ethanol loss is proportional to the square of the sugar concentration in the juice and that as fermentation temperature increases, ethanol loss increases exponentially[1]. These researchers reported a good agreement between the estimates of ethanol loss using the model with available experimental measurements.

Using these emission factors and the activity data expressed as gallons of wine fermented, ethanol emissions were estimated for the two different types of wine: white and red. The relative proportion of the two types of wine fermented in California were based on California Agricultural Statistics Services report entitles "Grape Crush Final Report, 2001-2002 Crop"[4]. The amount of wine grapes crushed for red wine and white wine was used to estimate the ratio of these wines fermented in the state. A composite emission factor of 4.7 lb/1000 gal of wine fermented was derived by using this ratio of wine grape types crushed (see sample calculations).

The statewide ethanol emissions for 2002 from wine fermentation are presented by air basin and county in Table II.

ASSUMPTIONS

1. Wine fermentation is proportional to the permitted wine production limit, which can be used to apportion the county wine production totals to the COABDIS regions.

2. The amount of grapes crushed for each type of wine is proportional to the amount of that type of wine fermented, which can be used to apportion the amount of total wine fermented into the amounts of red and white wine fermented.

3. The relative ratios of red and white wines produced in California are the same for all regions in the state.

4. The emission factors taken from the Williams and Boulton model run generated by the ARB are the best available to represent the amount of evaporative ethanol loss from the fermentation of wine.

COMMENTS AND RECOMMENDATIONS

The current procedure for estimating ethanol emissions from wine fermentation has the following limitations:

1. The estimated wine fermentation in each COABDIS region calculated by disaggregating the county level wine fermentation data based on the permit limits for wine production may not accurately reflect the actual wine

fermentation in each COABDIS region. This is because the permit limit is not a measure of actual fermentation but of maximum allowable production. Each winery will set this level based on business considerations. However, this is a reasonable surrogate and should not skew the breakout of wine fermentation by COABDIS region to any great degree.

2. The ratios of white to red wine are based on crushed grape ratios and that for the state. This leads to two possible errors. The first being the amount of wine fermented by crushing a given mass of white wine grapes may not be equal to the wine fermented by crushing the same mass of red wine grapes. The second is the assumption that all counties have the same ratio of fermentation of red to white wine, which is equal to the statewide crushed grape ratios.

A survey of the wine fermentation districts could be conducted to obtain COABDIS region specific data on the relative ratios of the different types (red and white) of wine fermented, rather than relying on a statewide grape crush ratio.

CHANGES IN METHODOLOGY

The current methodology has changed the method and surrogate used to determine wine fermentation by COABDIS region from those used in the previous 1992 update. The method for determining the temporal distribution of wine fermentation emissions has also changed, but the emission factors have remained the same, with the only difference being that all wines are now grouped into only two categories, red or white, whereas the previous methodology included a third category: rose wines.

Previously, amounts of grapes crushed by wine district and amount of grapes produced by county were used to disaggregate the statewide wine fermentation to the counties, but this has a greater potential for error than the current method. Grapes crushed are only recorded at the wine district level, and had to be further disaggregated itself to the county level using the amount of grapes produced by county. Unfortunately, grapes produced in a county may not be used by that county, being shipped to another place for fermentation of wine for example. Nor will all the grapes produced even be used for wine. Some are used for table grapes, making raisins and making grape juice. This introduced error in dividing up the wine to the counties. Furthermore, grapes crushed in a district may not be used in that district, being shipped to another place for the actual fermentation process. The new method uses directly reported wine fermentation at the county level from the TTB, disaggregating this to the COABDIS region level using the DABC’s wine production permit limit which is more directly related to each winery’s ability to ferment wine.

The temporal factor changes reflect the use of a new data source from the TTB, which breaks out wine fermentation by month on a county level basis.

TEMPORAL ACTIVITY

Ethanol emissions are distributed monthly based on the 2002 reported wine fermentation at the county level for that month as shown in Table II. During each month, it is assumed that emissions occur 24 hours per day and seven days a week. Below is a summarized temporal distribution using a statewide average of all county specific distributions to give some idea of how wine fermentation emissions are distributed by month.

2002 Statewide Wine Fermentation Emissions Distribution

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
4.8	2.9	0.9	0.6	0.7	0.8	0.8	5.9	27.4	29.6	11.7	13.8

SAMPLE CALCULATIONS

A. Calculate statewide ratios of white and red wine production.

Determine the tons of grapes crushed for each type of wine compared to the total tons of grapes crushed for both types in 2002.

CA red wine fermentation ratio = 1,816,715.6 tons red wine grapes crushed/ 3,104,580.9 tons of both wine grapes crushed
= 0.585 (58.5%)

CA white wine fermentation ratio = 1,287,865.3 tons white wine grapes crushed/ 3,104,580.9 tons of both wine grapes crushed
= 0.415 (41.5%)

B. Calculate composite emission factor.

Red wine TOG emission factor (6.2 lb/1000 gallons) x 0.585 +
White wine TOG emission factor (2.5 lb/1000 gallons) x 0.415 = 4.7 lb/1000 gallons

REFERENCES

1. L.A. Williams & R. Boulton. Modeling and Prediction of Evaporative Ethanol Loss During Wine Fermentation, American Journal of Enology and Viticulture, 32:234-242, (1983).

2. California Department of Alcoholic Beverage Control, David Kurano (916) 419-2548.

3. Air Resources Board, A Suggested Control Measure for Control of Ethanol Emissions from Winery Fermentation Tanks, a Technical Support Document Prepared by the Energy Section, Stationary Source Division, ARB, California, (October 1991).

4. http://www.nass.usda.gov/ca/bul/crush/Final/2002/200203gcbtb01.htm

UPDATED BY

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Table I

Wine Production Permit Limits in California by County and Air basin (1000 Gallons)

County	AB	Maximum Allowed Wine Production
ALAMEDA	SF	7,560
AMADOR	MC	2,905
BUTTE	SV	65
CALAVERAS	MC	1,315
CONTRA COSTA	SF	105
EL DORADO	MC	1,275
FRESNO	SJV	113,190
HUMBOLDT	NC	70
KERN	SJV	21,205
LAKE	LC	4,375
LASSEN	NEP	5
LOS ANGELES	SC	1,175
LOS ANGELES	MD	10
MADERA	SJV	19,370
MARIN	SF	95
MARIPOSA	MC	45
MENDOCINO	NC	15,285
MERCED	SJV	59,005
MODOC	NEP	5
MONTEREY	NCC	23,430
NAPA	SF	84,415
NEVADA	MC	150
ORANGE	SC	20
PLACER	SV	45
PLACER	MC	5
RIVERSIDE	SC	2,085
RIVERSIDE	SS	20
SACRAMENTO	SV	1,055
SAN BENITO	NCC	13,465
SAN BERNARDINO	SC	30
SAN DIEGO	SD	330
SAN FRANCISCO	SF	25
SAN JOAQUIN	SJV	120,500
SAN LUIS OBISPO	SCC	30,865
SAN MATEO	SF	160
SANTA BARBARA	SCC	10,145
SANTA CLARA	SF	5,700
SANTA CRUZ	NCC	2,955
SHASTA	SV	10
SISKIYOU	NEP	15
SOLANO	SV	15
SOLANO	SF	225
SONOMA	NC	47,660
SONOMA	SF	26,985
STANISLAUS	SJV	63,055
TEHAMA	SV	5
TRINITY	NC	40
TULARE	SJV	16,020
TUOLUMNE	MC	30
VENTURA	SCC	145
YOLO	SV	5,240
YUBA	SV	105
TOTAL		**702,010**

Table II

2001 Area Source Emissions
Activity: Wines & Brandy
Process: Food & Agricultual
Entrainment: Process Loss
Dimn: Fermentation (Wine) Wine
CES: 47068
Process Rate Unit: 1000 Gallons Fermented Per Year

County	AB	Process Rate	TOG (Tons/Year)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ALAMEDA	SF	3,487	8.19	2.2	0.3	0.1	0.1	0.5	0.0	0.0	0.0	8.2	39.1	33.6	15.8
AMADOR	MC	2,032	4.77	1.0	0.2	1.8	0.0	0.0	0.0	0.0	0.0	2.3	34.2	23.8	36.8
BUTTE	SV	43	0.10	0.0	0.0	10.3	2.9	1.5	0.0	0.0	5.9	41.2	4.4	0.0	33.8
CALAVERAS	MC	589	1.39	18.8	0.0	4.8	0.0	0.0	0.0	0.0	0.0	9.2	13.7	12.8	40.7
CONTRA COSTA	SF	1,405	3.30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.2	49.5	30.8	12.5
EL DORADO	MC	641	1.51	1.3	0.0	3.1	0.0	0.0	0.0	0.0	0.0	5.8	42.3	13.5	34.0
FRESNO	SJV	176,392	414.52	0.1	0.2	0.2	0.1	0.1	0.0	0.1	10.8	48.4	29.0	10.3	0.7
HUMBOLDT	NC	160	0.37	3.2	0.0	14.0	0.0	14.3	12.5	0.7	0.0	12.7	16.7	14.7	11.1
KERN	SJV	34,278	80.55	0.0	0.4	0.0	0.8	0.0	0.0	0.0	10.7	43.8	33.9	7.8	2.6
LAKE	LC	3,653	8.58	33.9	0.6	0.0	0.0	0.0	0.0	0.0	0.5	2.3	1.3	3.8	57.6
LASSEN	NEP	3	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100
LOS ANGELES	SC	148	0.35	0.1	0.0	0.0	0.0	0.0	9.0	0.0	0.0	22.9	11.1	0.8	56.1
LOS ANGELES	MD	1	0.003	0.1	0.0	0.0	0.0	0.0	9.0	0.0	0.0	22.9	11.1	0.8	56.1
MADERA	SJV	139,317	327.40	3.0	1.1	1.5	1.4	1.4	1.3	3.3	5.9	26.0	32.3	9.7	13.1
MARIN	SF	38	0.09	0.0	0.0	0.0	0.0	0.0	4.8	0.0	21.5	7.8	14.7	16.6	34.6
MARIPOSA	MC	25	0.06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.1	45.0	0.0	4.9
MENDOCINO	NC	13,169	30.95	5.5	0.8	0.5	2.1	2.2	0.9	0.0	0.0	1.1	6.9	28.7	51.2
MERCED	SJV	67,426	158.45	0.8	0.4	0.0	0.0	0.0	0.0	0.0	1.5	33.4	49.5	8.3	6.2
MONTEREY	NCC	50,056	117.63	43.1	32.4	2.0	0.1	0.8	3.5	0.0	0.0	0.3	1.4	3.1	13.2
NAPA	SF	79,242	186.22	4.0	6.1	3.2	1.4	1.1	1.0	1.0	1.1	10.6	16.5	16.8	37.2
NEVADA	MC	63	0.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.4	44.5	2.4	40.8
ORANGE	SC	4	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100
PLACER	MC	1	0.002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.6	86.4
PLACER	SV	8	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.6	86.4
RIVERSIDE	SC	519	1.22	0.0	0.0	2.8	0.6	2.4	4.5	0.0	0.0	1.3	33.6	28.1	26.7
RIVERSIDE	SS	5	0.01	0.0	0.0	2.8	0.6	2.4	4.5	0.0	0.0	1.3	33.6	28.1	26.7
SACRAMENTO	SV	10	0.02	8.4	9.6	14.4	0.0	9.6	0.0	0.0	0.0	9.6	0.0	0.0	48.3
SAN BENITO	NCC	6,408	15.06	0.5	0.0	0.0	0.6	0.0	0.0	0.0	0.0	3.6	21.5	9.4	64.5
SAN BERNARDINO	SC	19	0.05	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.5	50.4	28.1	0.0	5.0
SAN DIEGO	SD	144	0.34	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	8.4	1.5	89.5
SAN FRANCISCO	SF	54	0.13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	70.9	19.7	9.4
SAN JOAQUIN	SJV	229,674	539.73	2.1	0.2	0.0	0.0	0.0	0.0	0.0	3.4	27.9	43.8	14.4	8.2
SAN LUIS OBISPO	SCC	23,253	54.64	23.3	2.2	1.7	0.3	0.1	0.3	0.3	0.3	4.6	22.8	28.0	16.1
SAN MATEO	SF	66	0.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.4	7.5	60.1	27.0
SANTA BARBARA	SCC	10,402	24.45	7.9	0.9	0.7	1.3	5.1	0.4	0.2	0.4	1.3	4.8	3.9	73.2
SANTA CLARA	SF	4,831	11.35	8.2	1.2	4.5	0.2	3.3	10.1	12.8	3.7	2.6	6.2	6.8	40.6
SANTA CRUZ	NCC	1,112	2.61	28.6	9.7	1.7	0.2	0.1	4.3	1.0	0.9	15.3	14.4	9.7	14.2
SHASTA	SV	7	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	35.1	0.0	0.0	64.9
SISKIYOU	NEP	8	0.02	0.0	33.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.8	0.0	47.9
SOLANO	SF	237	0.56	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2	43.9	43.0	8.9
SOLANO	SV	16	0.04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2	43.9	43.0	8.9
SONOMA	NC	56,071	131.77	7.4	5.1	2.2	2.0	1.9	1.4	1.2	1.0	5.6	18.3	17.7	36.3
SONOMA	SF	31,748	74.61	7.4	5.1	2.2	2.0	1.9	1.4	1.2	1.0	5.6	18.3	17.7	36.3
STANISLAUS	SJV	58,503	137.48	0.4	2.8	0.9	0.5	3.1	3.5	2.8	13.9	27.8	26.2	9.5	8.7
TEHAMA	SV	1	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100
TRINITY	NC	55	0.13	1.2	1.1	1.2	0.0	0.0	0.0	0.0	0.0	0.5	11.7	78.8	5.5
TULARE	SJV	57,521	135.17	0.0	0.3	0.0	0.0	0.0	0.0	0.0	22.3	59.8	17.5	0.0	0.1
TUOLUMNE	MC	28	0.07	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100
VENTURA	SCC	40	0.09	21.1	0.8	7.1	0.1	0.0	0.0	0.0	0.0	0.0	7.5	0.8	62.7
YOLO	SV	7,692	18.08	3.8	0.0	0.8	0.1	0.4	0.0	0.0	0.0	12.4	64.2	10.1	8.2
YUBA	SV	51	0.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	99.4	0.0	0.6
STATEWIDE		**1,060,656**	**2,492.55**	**4.8**	**2.9**	**0.9**	**0.6**	**0.7**	**0.8**	**0.8**	**5.9**	**27.4**	**29.6**	**11.7**	**13.8**

Fraction of Reactive Organic Gases (FROG): 1.0000
(Reactive Organic Gases (ROG) Emissions = TOG X FROG)