

# High Alcohol Wine Production from Grape Juice Concentrates

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*Improved fermentation methods for grape juice concentrates could allow fermentation of high alcohol wines from concentrate, which may eliminate brandy fortification, provide an easier process to produce dessert wines, and prevent stuck fermentations. Two studies to determine fermentation conditions for the production of high alcohol wine from grape juice concentrates were conducted. The yeast strain in both studies was *Saccharomyces cerevisiae* L2226. Wines were fermented in flasks on an orbital shaker to increase fermentation rate and keep the yeast cells suspended. Study 1 investigated the production of high alcohol wine from concentrates of four varieties (Chardonnay, Chenin blanc, Rubired, and Sauvignon blanc) reconstituted from 68 to 35 °Brix, inoculated with different yeast levels (4 x 10<sup>6</sup> or 17 x 10<sup>6</sup> cells/mL), and with nutrients (Fermaid or diammonium phosphate) added alone or in combination. Treatments containing the highest inoculation level and nutrients resulted in the highest alcohol content. The highest alcohol level (18.15%) was achieved using Sauvignon blanc concentrate inoculated with 17 x 10<sup>6</sup> cells/mL yeast and 2 g/L each of Fermaid and diammonium phosphate. Study 2 examined aeration (0, 0 to 48, and 30 to 48 hr), nutrient addition method (at the start or in increments), and fermentation of 20 °Brix juice with supplementation of concentrate during fermentation versus starting the fermentation at 35 °Brix. High alcohol wines (over 20%) were made by fermentation of grape juice concentrate. Moderate aeration of fermenting juice resulted in higher alcohol levels than treatments that were not aerated. The addition of nutrients in increments resulted in lower alcohol concentrations than treatments with nutrients added at the start of fermentation. The addition of concentrate during fermentation decreased production of alcohol compared to fermentation at 35 °Brix. The highest mean alcohol level (20.96%) was produced from 35 °Brix juice aerated 0 to 48 hr with nutrients added at the start of fermentation.*

Grape juice concentrate is used to make wine in many locations that do not or cannot grow grapes [29]. Grape juice concentrate can be easily stored, allowing winemakers to produce wine throughout the year. Concentrate is more resistant to spoilage and is less expensive to handle and transport than unconcentrated grape juice [45]. High alcohol wine is currently produced by the addition of brandy to wine during fermentation because some yeast strains do not remain viable when ethanol is above 14% v/v. The addition of brandy during fermentation results in yeast death due to the toxic effects of high alcohol levels [10]. There are many regulations regarding the addition, storage, and handling of brandy.

The fermentability of grape juice is related to cultivar, environment, fertility of soil, conditions of maturity at harvest, and treatment of grapes in the winery [4,8,40,46]. Stuck or sluggish fermentations in juice concentrates may result from inadequate yeast growth caused by prefermentation processing of juice or by the concentration process [5,7,8,21,40,41,42]. Low nutrient content, high sugar levels, lack of oxygen and agitation, improper yeast type selection, and low inoculation levels are factors that can contribute to stuck fermentations.

Yeast nutrients are used in winemaking to increase yeast growth and fermentation rate and to ensure a complete fermentation [2,11,15,18,28,30,31,35,36,37,41]. Assimilable nitrogen from low molecular-weight nitrogenous compounds such as ammonium ions and amino acids is an essential nutrient for yeast growth [13,15,20]. Nitrogen is used by the yeast for synthesizing structural proteins, enzymes, nucleic acids, and pyrimidine nucleotides [6,7,22]. Assimilable nitrogen has been shown to increase sugar fermentation and ethanol formation [1]. Nitrogen in the juice can be increased by addition of fertilizers in the vineyard or diammonium phosphate (DAP) and other nutrients to the juice [1]. The amount of DAP that can be legally added to wine fermentations in the United States is 960 mg/L.

High osmotic pressure caused by high sugar concentrations can contribute to stuck fermentations [21,43]. Higher inoculation levels of yeast should be used to ferment juice with high sugar concentrations [9,32,40]. Strains of *Saccharomyces cerevisiae*, such as L2226, have been recommended in high sugar fermentations as they can be more tolerant to high sugar levels than other yeast strains [22].

Oxygen content can affect alcohol levels because oxygen is used by yeast to synthesize yeast membrane components [25,33]. Presence of oxygen in wine during the early stages of fermentation does not appear to significantly affect color or flavor of wine. Oxidation has been shown to benefit musts by reducing the level of phenolic compounds, which helps to preserve wine freshness, develop complexity, and age longer than white wines with high phenolic levels [18,24]. However, some winemakers believe oxidation reduces wine quality.

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Aeration at the optimal level increased yeast numbers and vigor leading to increased rates of fermentation and alcohol during fermentation [17,19]. The addition of oxygen to juice containing low levels of free amino nitrogen increased cell multiplication and fermentation rates. Oxygen addition 12 hr after inoculation enhanced very high gravity fermentation using commercial lager yeast strains [33]. Ingledew and Kunkee [16] evaluated flushing the headspace of fermentations with air for different durations and found the optimum aeration time was between 30 and 72 hr.

Agitation of fermentations can provide enough oxygen to allow sufficient yeast growth. For larger volume fermentations, aeration can be provided by sparging air through the fermentation medium [39]. Agitation during fermentation also allows yeast and solids in the fermenting juice to remain in suspension and is commonly practiced in the fermentation of sherry [3]. Agitation is especially beneficial in fermentation of clarified juices made from concentrate because the juices contain very few solids that would help keep the yeast in suspension [23,29]. Groat and Ough [14] found that stirring enhanced the ability of the wine to ferment completely and rapidly.

Increasing yeast inoculation rates alleviates fermentation problems caused by limited nitrogen [26,34]. It is possible to increase ethanol yield and the survival of yeast at high concentrations of ethanol by altering the nutritional conditions [47,48]. Inoculation levels of 750 million cells/g of mash were found to produce more ethanol than inoculation levels of 30 and 300 million cells/g of mash [47]. The following are recommended inoculum levels for a given soluble solids level ( $^{\circ}$ Brix) to help prevent stuck fermentation in wine:  $2 \times 10^6$  cells/mL for less than initial  $20^{\circ}$ Brix;  $2$  to  $4 \times 10^6$  cells/mL for  $20$  to  $24^{\circ}$ Brix;  $4$  to  $6 \times 10^6$  cells/mL for  $25$  to  $30^{\circ}$ Brix; and, if greater than initial  $30^{\circ}$ Brix,  $1 \times 10^6$  additional cells/mL for each  $^{\circ}$ Brix to be fermented [9].

The first objective was to investigate the production of high alcohol wines made from grape juice concentrate reconstituted from  $68$  to  $35^{\circ}$ Brix using different yeast inoculation levels and different levels of nutrients (Fermaid and DAP) alone or in combination. The second objective was to determine the effect of aeration, nutrient addition method, and starting the fermentation with  $20^{\circ}$ Brix juice with addition of concentrate during fermentation as opposed to starting the fermentation with  $35^{\circ}$ Brix on the production of alcohol levels of  $20\%$  or higher in wine made from grape juice concentrate.

#### Materials and Methods

**Concentrate preparation.** Concentrates for both studies were obtained from Canandaigua Wine Company (Madera, CA). Concentrates ( $68^{\circ}$ Brix) were diluted with deionized water and allowed to reach room temperature ( $21^{\circ}$ C) prior to yeast inoculation. Soluble solids was determined using a Bausch and Lomb ABBE Mark II refractometer (Scientific Instruments, Keene, NH).

**Yeast strain and preparation.** Active dry wine yeast (*Saccharomyces cerevisiae* L2226) obtained from Lallemand, Inc. (Montreal, Quebec) were used in both studies. Yeast were stored at  $2^{\circ}$ C and rehydrated with  $41^{\circ}$ C tap water ( $10$  mL water/g of yeast) for  $10$  min, then stirred for five sec and rehydrated for another  $10$  min. Following rehydration, yeast were added to grape juice at room temperature ( $21^{\circ}$ C). After inoculation, the juice was thoroughly shaken to ensure even distribution. Total yeast inoculation levels were estimated by manufacturer's recommendations and verified using a Quebec colony counter. Inoculation levels (cells/mL) were reported within each study.

**Flask preparation.** Grape juice samples ( $200$  mL) were fermented in  $250$  mL Erlenmeyer flasks containing three  $4$  mm glass boiling beads. Fermaid K (Lallemand, Inc.) and DAP (Presque Isle Wine Cellars, North East, PA) were added to each flask. Fermaid K contains DAP, magnesium sulfate, inactive yeast, folic acid, thiamine, niacin, and calcium pantothenate. One drop of liquid antifoam (Presque Isle Wine Cellars) was added to each flask prior to inoculation to prevent foaming. The flasks of inoculated grape juice received various treatments as described for each study. Fermentation locks containing  $100$  mg/L potassium metabisulfite were placed in rubber stoppers for each experiment to seal the flask. To reduce the amount of evaporation of the sulfite solution, the fermentation locks were loosely capped. Samples were fermented on an orbital shaker at  $20^{\circ}$ C. Completion of fermentation was determined by monitoring the weight of the flasks. The fermentations were considered complete or stuck when no further weight change was indicated. Upon fermentation completion, the samples were stored at  $2^{\circ}$ C for  $24$  hr. After cold settling, the cleared portion of wine in each flask was decanted into  $125$  mL glass bottles and stored at  $2^{\circ}$ C until analyzed.

**Treatments.** Study I: Chardonnay, Chenin blanc, Rubired, and Sauvignon blanc grape juice concentrates were used. Each variety was reconstituted to  $35^{\circ}$ Brix. Mineral analysis and chemistry are reported in Table 1. The juices were inoculated with either  $17 \times 10^6$  cells/mL or  $4 \times 10^6$  cells/mL of *Saccharomyces cerevisiae* L2226. For each variety, four nutrient treatments per inoculation level were added: (1) no Fermaid or DAP; (2) Fermaid ( $2$  g/L); (3) DAP ( $2$  g/L); and (4) both Fermaid and DAP ( $2$  g/L). The flask contents were fermented on an orbital shaker at  $100$  rpm at  $20^{\circ}$ C. Flask weights were recorded every  $48$  hr to determine the end of fermentation.

Table 1 Soluble solids, pH, tartaric acid, and free amino nitrogen content of juice made from concentrates.

Varietal	Soluble solids (*Brix)	pH	TA	Free amino
			(% tartaric acid)	nitrogen (mg/L)
Chardonnay	22.2	3.60	0.51	161.6
Chenin blanc	16.4	3.81	0.34	113.9
Rubired	18.1	3.98	0.49	114.7
Sauvignon blanc	20.9	3.54	0.46	176.8

*Study 2:* Chardonnay juice concentrate was used. The free amino acid concentration of the concentrate reconstituted to 35 °Brix was 455 mg/L and the fructose/glucose ratio was 1.00.

*Saccharomyces cerevisiae* L2226 was used at a level of  $35 \times 10^6$  cells/mL. Yeast extract (0.36 g/L) (Extrarome LS-65, Scott Laboratories, Petaluma, CA) was added during yeast rehydration to promote the rehydration process. The yeast and yeast extract mixture were added to grape juice. Although yeast extract contains nutrients, additional nutrient was evaluated. Fermaid (0.24 g/L) and DAP (0.86 g/L) were added to each flask in each experiment. The flasks of inoculated grape juice received various treatments as described for each experiment below. Aeration treatments were applied by allowing the flask to remain open for the specified treatment time. After aeration treatments, the flasks were flushed with nitrogen gas, which is inert and does not act as a source of nitrogen for the yeast. Samples were fermented on an orbital shaker at 200 rpm at 20°C. Each treatment was replicated using three flasks per treatment. Some experiments were repeated on different dates using the same treatments.

**Experiment 1: Effect of aeration and nutrient addition on alcohol level in wine produced from fermentation of 35 °Brix grape juice.** Inoculated juice (200 mL) and antifoam were added to each flask. DAP and Fermaid were added at the start or in three equal increments (0, 47, and 71 hr) during fermentation. Each increment was one-third of the total nutrients added. For each nutrient addition method, aeration was performed for 0, 0 to 48, and 30 to 48 hr. Flasks were fermented on an orbital shaker, and completion of fermentation was determined by weighing the flasks. This experiment was conducted twice.

**Experiment 2: Effect of aeration, nutrient addition, and grape juice concentrate supplementation on alcohol level in wine produced from fermentation of 20 °Brix grape juice.** Inoculated juice (146 mL) and antifoam were added to each flask. Grape juice concentrate was added in two increments of 34.76 g each at 30 and 70 hr. DAP and Fermaid were added all at the start or in three equal increments (0, 47, and 71 hr) during fermentation. Each increment was one-third of the total nutrients added. For each nutrient addition method, aeration was performed for 0, 0 to 48, and 30 to 48 hr. Flasks were fermented on orbital shaker, and completion of fermentation was determined by weighing the flasks.

Alcohol analysis. The alcohol content of both studies was expressed as % v/v.

*Study 1:* Alcohol levels were measured using a DujardinSalleron Model 360 ebulliometer (Paris, France). Wines were diluted 1:1 with deionized water.

*Study 2:* Alcohol concentration was determined with high-performance liquid chromatography (HPLC). Two columns, a Hypersil ODS (Hewlett Packard 79916OD-554) and an Aminex (HPX-87H; Bio-Rad, Hercules, CA), were used in series and maintained at 65°C. A cation H+ guard column (125-0129; BioRad) was used. The mobile phase was 0.065% H<sub>3</sub>PO<sub>4</sub> at a flow rate of 0.7 mL/min. The detector was a differential refractometer (Waters, Milford, MA) set at 35°C. Prior to injection, each wine sample was diluted 1:1 with deionized water. Injection volume was 10 µL with a sample run time of 23 min. Alcohol level was quantified using ethanol as an external standard.

**Fructose/glucose ratio.** Fructose/glucose ratio for the concentrate reconstituted to 35 °Brix was determined using the same HPLC procedure for analyzing ethanol concentration. Fructose and glucose contents were quantified using external standards.

**pH and titratable acidity.** Sample pH was measured with a pH meter (Cole-Parmer Instrument Co., Vernon Hills, IL) at 21 °C. Titratable acidity (TA) was measured by titrating 5 mL of wine sample in 125 mL deionized water to pH 8.2 with 0.1 N NaOH. Results were expressed as % tartaric acid.

**Free amino nitrogen.** A modified ninhydrin method was used for assaying free amino nitrogen [12,38]. The ninhydrin reagent contained 2 g ninhydrin, 0.3 g hydrantin in 75 mL dimethyl sulfoxide, and 25 mL 4M lithium acetate buffer (pH 5.2). The dilution solution was 50% ethanol and water. Glycine was used as the external standard. Residual sugars. Residual reducing sugars were determined using Miller's reducing sugar assay [27].

**Statistical analyses.** *Study 1:* The resulting alcohol levels were analyzed using statistical analysis system (SAS). Data was conducted as a completely randomized design with multiple comparison of means using least significant

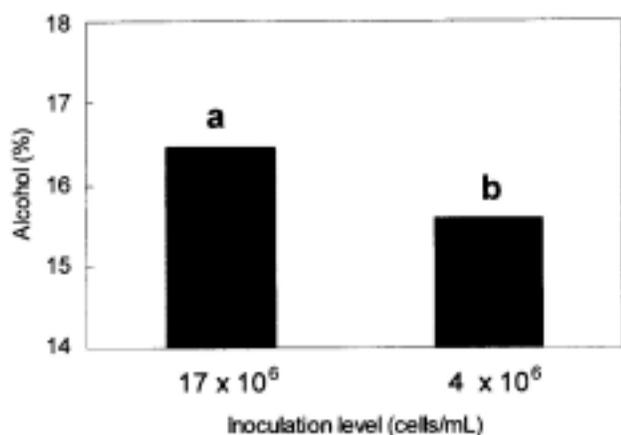
difference [44]. For each variety there were two inoculation levels ( $17 \times 10^6$  or  $4 \times 10^6$  cells/mL) with four nutrient treatments per inoculation level: no Fermaid or DAP, Fermaid (2 g/L), DAP (2 g/L), and both Fermaid and DAP (2 g/L). Rubired, Chenin blanc, and Sauvignon blanc had two replications, while Chardonnay had three replications. Statistical differences were expressed at alpha level 0.05.

**Study 2:** The data represent the mean of six flasks for experiment 1 as it was conducted on two different dates with three flasks per treatment on each date. The data for experiment 2 represent the mean of three flasks. Statistical analysis using SAS examined the means separated by Duncan's multiple range test for the alcohol results ( $\alpha = 0.05$ ). The general linear model sources of variation for the first experiment were experiment date (1 or 2), nutrient addition method, aeration time, nutrient addition method\*aeration time, and experiment date\*nutrient addition method\*aeration time. In experiment 2, the sources of variation were nutrient addition method, aeration time, and nutrient addition method\*aeration time. Variation among the flasks was used to determine the error term for both of the experiments.

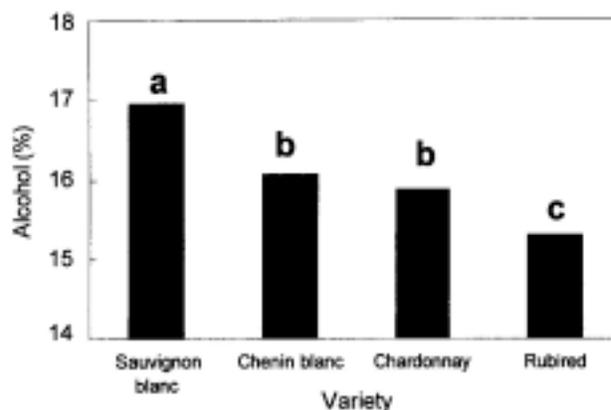
## Results and Discussion

**Study 1.** The fermentation treatments containing the highest inoculum level ( $17 \times 10^6$  cells/mL) across all varieties and all treatments created the highest mean alcohol level (16.48%) (Figure 1). This indicates that to achieve a high alcohol level when fermenting reconstituted juice, it is necessary to inoculate the juice with a large number of viable yeast cells, as reported by other researchers [15,16].

*Sauvignon blanc* had the highest alcohol content (16.94%). Chenin blanc (16.09%) and Chardonnay (15.93%) contained similar levels, while Rubired (15.31 %) contained the lowest level



**Figure 1** Effect of inoculation level on alcohol levels (% v/v) of wine fermented from 35 °Brix juice from concentrate. Means with the same letter are not significantly different, LSD = 0.3431.



**Figure 2** Effect of variety on alcohol levels (% v/v) of wine fermented from 35 °Brix juice from concentrate. Means with the same letter are not significantly different, LSD = 0.3828.

(Figure 2). Results were analyzed by variety, as it was a significant factor. Alcohol levels of each variety are reported in Table 2.

The highest mean alcohol level (16.43%) in Chardonnay was achieved with the  $1.7 \times 10^6$  cells/mL inoculation level with both Fermaid and DAP added. The lowest alcohol value (15.13%) was obtained at the lowest inoculation level, with no nutrients present, and was significantly lower than all other treatments at both inoculation levels.

The highest mean alcohol level (16.70%) in Chenin blanc was achieved with the  $17 \times 10^6$  cells/mL inoculation level and with 2 g/L DAP added. The  $17 \times 10^6$  cells/mL inoculation level with nutrients added resulted in alcohol levels that were all higher than the  $4 \times 10^6$  inoculation levels. The lowest alcohol level (15.30%) was obtained at the  $4 \times 10^6$  cells/mL inoculation level, with no nutrients added, and was significantly lower than all  $17 \times 10^6$  cells/mL inoculation levels.

The highest mean alcohol level (16.5%) in Rubired was achieved at the highest inoculation level, with both nutrients added. The lowest alcohol level (13.9%) was achieved with the lowest inoculation level, with 2 g/L Fermaid and no DAP present, and was significantly lower than all fermentation treatments.

The highest mean alcohol level (18.15%) in Sauvignon blanc was achieved at the highest inoculation level with both nutrients added. The lowest alcohol content (16.2%) was obtained at the lowest inoculation level with only DAP present.

These results show that the highest alcohol levels were achieved when the reconstituted juice was inoculated with the highest level of yeast ( $17 \times 10^6$  cells/mL) with nutrients present. The fermentations with the lowest alcohol values were inoculated with the lowest inoculum ( $4 \times 10^6$  cells/mL) and had the least amount of nutrients present (Figure 3). These

results show that successful fermentation of high sugar concentrations can be accomplished if juices are fortified with nitrogenous yeast foods and high levels of inoculated yeast are used. Under such conditions, final alcohol levels are maximized.

**Study 2. Experiment 1:** The fermentations were completed 16 days after initiation. There was no significant difference for alcohol levels produced in this experiment, which was repeated on two different dates (19.73 and 19.79%). There was no significant interaction for nutrient addition method\* aeration time.

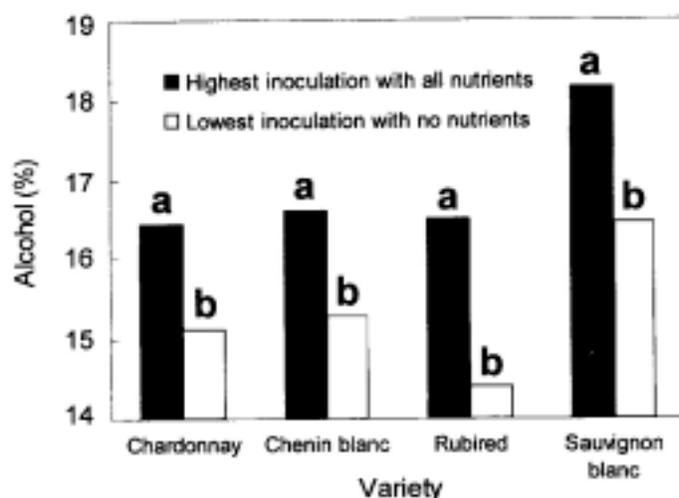
Alcohol level produced by nutrients added at the start of fermentation (20.08%) was significantly higher than treatments with nutrients added in increments during fermentation (19.49%) (Figure 4). The aeration of flasks during fermentation resulted in higher alcohol levels than treatments with no aeration. Alcohol levels were significantly different for each aeration treatment (Figure 5). Aeration for 0 to 48 hr produced the highest alcohol level (20.72%), followed by 30 to 48 hr aeration (19.50%), while no aeration produced the lowest alcohol level (19.03%). The highest alcohol level (20.96%) was at the start of fermentation (Figure 6).

**Table 2** Effect of inoculation level and nutrient addition on alcohol level (%v/v) of 35 °Brix Chardonnay, Chenin blanc, Rubired, and Sauvignon blanc fermented from concentrate.

Inoculation level (cells/mL)	Fermaid (g/L)	DAP <sup>a</sup> (g/L)	Alcohol level			
			Chardonnay	Chenin blanc	Rubired	Sauvignon blanc
17 x 10 <sup>6</sup>	0	0	15.87 ab <sup>b</sup>	16.10 ab	15.75 ab	17.05 bc
17 x 10 <sup>6</sup>	0	2	15.93 ab	16.70 a	15.90 a	16.80 cd
17 x 10 <sup>6</sup>	2	0	16.20 ab	16.60 a	16.15 a	17.60 ab
17 x 10 <sup>6</sup>	2	2	16.43 a	16.60 a	16.50 a	18.15 a
4 x 10 <sup>6</sup>	0	0	15.13 c	15.30 c	14.40 c	16.45 cd
4 x 10 <sup>6</sup>	0	2	15.73 b	15.65 bc	15.10 bc	16.20 d
4 x 10 <sup>6</sup>	2	0	15.77 b	15.90 bc	13.90 d	16.40 cd
4 x 10 <sup>6</sup>	2	2	15.93 ab	15.85 bc	14.80 c	16.90 cd

<sup>a</sup>Diammonium phosphate

<sup>b</sup>Means with the same letter within variety are not significantly different. LSD for Chardonnay, Chenin blanc, Rubired, and Sauvignon blanc are 0.5951, 0.6733, 0.7727, and 0.7528, respectively.



**Figure 3** Effect of inoculation level and nutrient addition on alcohol levels (% v/v) of wine from different varieties fermented from 35 °Brix juice from concentrate. Means with the same letter are not significantly different within variety. LSD for Chardonnay = 0.5951, Chenin blanc = 0.6733, Rubired = 0.7727, and Sauvignon blanc = 0.7528.

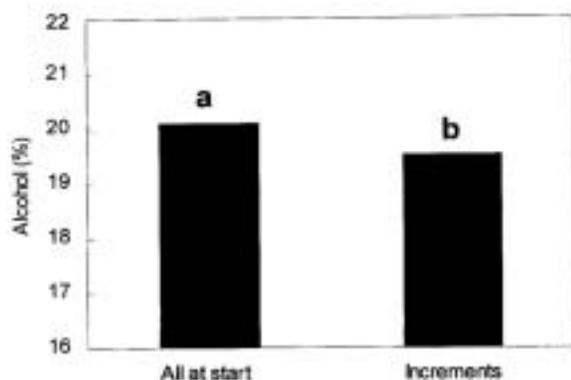


Figure 4 Main effect of nutrient addition method on alcohol level (% v/v) of wine fermented from 35 °Brix juice from concentrate (experiment 1). Means with the same letter are not significantly different, alpha = 0.05.

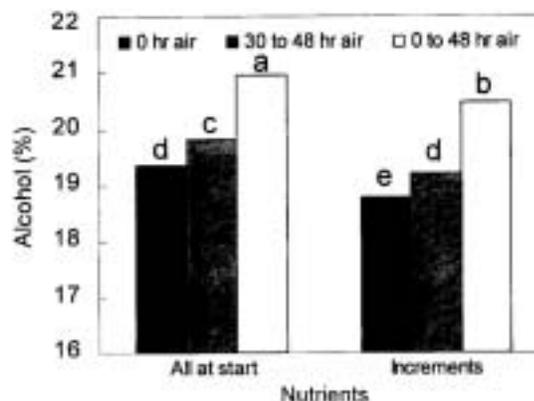


Figure 6 Effect of aeration time and nutrient addition method on alcohol level (% v/v) of wine fermented from 35 °Brix juice from concentrate (experiment 1). Means with the same letter are not significantly different, alpha = 0.05.

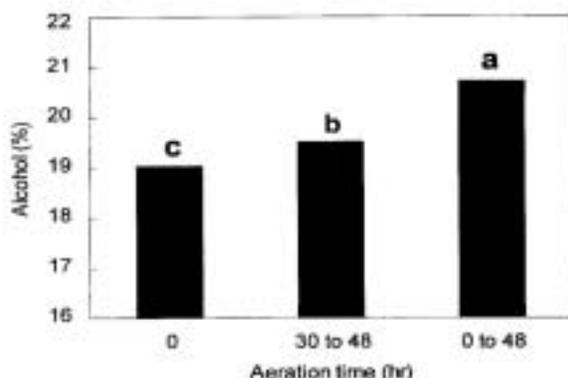


Figure 5 Main effect of aeration time on alcohol level (% v/v) of wine fermented from 35 °Brix juice from concentrate (experiment 1). Means with the same letter are not significantly different, alpha = 0.05.

The analysis of alcohol, residual reducing sugar, pH, and TA of the final wine fermented from 35 °Brix juice are shown in Table 3. Viable and total yeast cell counts conducted for the treatments aerated 0 and 0 to 48 hr indicated that aeration allowed greater yeast cell production than in samples that were not aerated (data not shown).

*Experiment 2:* Fermentations were completed in 17 days for all treatments, except the treatment with no aeration and nutrients added in increments during fermentation which completed 22 days after initiation. There was no significant interaction for nutrient addition method\*aeration time.

Nutrient addition methods did not produce a significant difference in alcohol levels produced during fermentation. Each aeration time produced significantly different alcohol levels (Figure 7). The highest alcohol level (20.09%) was produced by aeration for 0 to 48 hr, followed by aeration for 30 to 48 hr (19.10%), and the lowest (17.89%) was produced by no aeration. The highest alcohol level (20.11 %) was produced by aeration for 0 to 48 hr with addition of nutrients in increments during fermentation; however, this was not significantly different than the treatment aerated 0 to 48 hr with nutrients added at the start of fermentation (Figure 8).

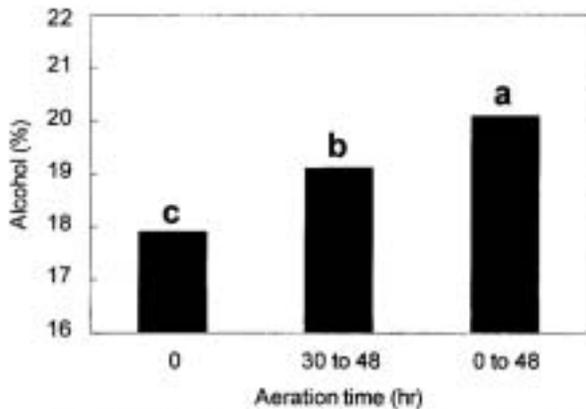
Table 3 Effect of aeration and nutrient addition method on wine fermented from grape juice (35 °Brix, pH 3.79, and 0.92% tartaric acid).

Aeration time (hr)	Nutrient addition	Alcohol level (% v/v)	Residual reducing sugar (%)	pH	TA (% tartaric acid)
0	All at start <sup>a</sup>	19.34	4.4	3.84	1.00
	Increments <sup>b</sup>	18.78	4.5	3.88	1.06
0 to 48	All at start	20.96	2.1	3.82	1.05
	Increments	20.49	2.6	3.93	1.04
30 to 48	All at start	19.81	3.2	3.87	1.07
	Increments	19.20	3.7	3.90	1.05

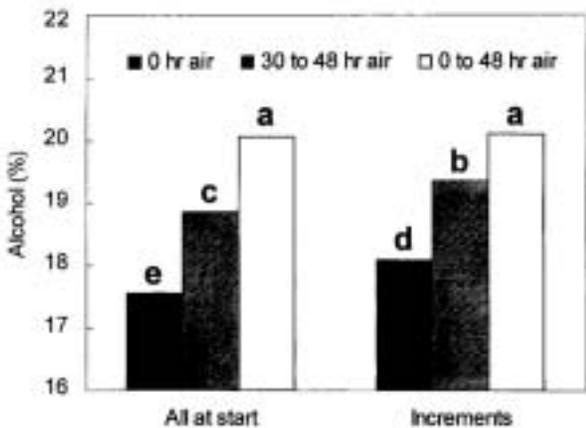
<sup>a</sup>All at start = nutrients added at the start of fermentation.

<sup>b</sup>Increments = nutrients added in increments (0, 47, and 71 hr) during fermentation.

The lowest alcohol level (17.58%) was produced by no aeration with addition of nutrients at the start of fermentation. Alcohol, residual reducing sugar, pH, and TA analysis of the final wine fermented from grape juice at 20 °Brix juice with concentrate added during fermentation to yield 35 °Brix are presented in Table 4.



**Figure 7** Main effect of aeration time on alcohol level (% v/v) of wine fermented from juice initially at 20 °Brix with concentrate added during fermentation to yield 35 °Brix (experiment 2). Means with the same letter are not significantly different, alpha = 0.05.



**Figure 8** Effect of aeration time and nutrient addition method on alcohol level (% v/v) of wine fermented from juice initially at 20 °Brix with concentrate added during fermentation to yield 35 °Brix (experiment 2). Means with the same letter are not significantly different, alpha = 0.05.

**Table 4** Effect of aeration and nutrient addition method on wine fermented from grape juice (pH 3.89 and 0.90% tartaric acid) initially at 20 °Brix, with concentrate added during fermentation to yield a total of 35 °Brix.

Aeration time (hr)	Nutrient addition	Alcohol level (% v/v)	Residual reducing sugar (%)	pH	TA (% tartaric acid)
0	All at start <sup>a</sup>	17.58	7.3	3.76	1.08
	Increments <sup>b</sup>	18.10	6.6	3.88	1.06
0 to 48	All at start	20.07	3.1	3.82	1.18
	Increments	20.11	3.0	3.89	1.16
30 to 48	All at start	18.86	5.4	3.81	1.09
	Increments	19.34	4.5	3.90	1.06

<sup>a</sup>All at start = nutrients added at the start of fermentation.

<sup>b</sup>Increments = nutrients added in increments (0, 47, and 71 hr) during fermentation.

## Conclusion

Addition of nutrients in the right combination at adequate levels reduced the level of stuck or sluggish fermentations in the production of high alcohol products made from grape juice concentrate. Addition of Fermaid and/or DAP with a high inoculation level produced high alcohol wines (up to 18.15%). Concentrate at 68 °Brix can be reconstituted to 35 °Brix and inoculated with a high level of yeast specifically developed for high alcohol production. Yeast and yeast nutrients can be added to replace any nutrient loss due to the concentrating unit and produce a high alcohol product without fortification of the wine.

High alcohol wines (over 20%) were produced from grape juice concentrate that was aerated from 0 to 48 hr and that had all nutrients added at the start of fermentation. The treatments that did not receive aeration had significantly lower alcohol levels compared to the treatments that were aerated for 0 to 48 hr in each experiment. The treatments with nutrients added incrementally during fermentation produced lower alcohol levels for one experiment and no effect in the other.

The addition of concentrate during the fermentation decreased

production of alcohol compared to the experiment that started with 35 °Brix juice.

The methods used in this research suggest that high alcohol wines can be produced directly from concentrate, which will be useful for wine production in those locations that do not or cannot produce grapes. Results indicate that aeration and nutrient addition stimulated alcohol levels produced by the yeast. Aeration by pumping the fermentation liquid over or sparging of the liquid with air may allow the production of 20% alcohol or more. Further research is needed to determine the effect of these treatments on the sensory attributes of the final product.

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