Chapter 4

Results

Part I: The optimal method of Krachai-Dam honey wine processing.

4.1. Effects of Krachai-Dam cultivars and yeast strains on Krachai-Dam honey wine qualities.

Physical and chemical qualities of wines influenced by 2 factors studied (Krachai-Dam cultivars and yeast strains) were shown in Table 4.1. As for Krachai-Dam cultivars (factor 1), there were significant differences in all quality parameters studied. 'Rom-Klao' wines had the highest TP, AOI and a* and the lowest L* and b*. As for yeast strains (factor 2), there were significant differences in 4 quality parameters studied (alcohol percentage, pH, TA and TP). 'Fermivin' wines had the highest TA and the lowest alcohol percentage and pH whereas 'Lalvin V1116' wines had the highest TP, alcohol percentage and pH.

Table 4.1 Effects of Krachai-Dam cultivars and yeast strains on Krachai-Dam honey wine qualities.

Factors	Physical and chemical qualities of wines								
	Wine color			Total soluble solid (°Brix)	Alcohol (% v/v)	pH	Total titrable acidity[1](g/l)	Total phenolic compounds[2]	Anti-oxidant index[3]
	L*	a*	b*						
Krachai-Dam cultivars[4] (factor 1)									
Rom-Klao	16.97 c	33.26 a	4.50 b	6.39 a	11.51 a	3.83 b	2.97 a	219.38 a	3.07 a
Nam-Juang	33.14 a	21.89 b	10.98 a	6.11 b	11.39 b	3.83 b	2.65 b	158.95 b	1.77 b
Kheg-Noi#2	30.07 b	23.90 b	9.70 a	6.41 a	11.50 a	3.97 a	2.95 a	138.83 c	1.74 b
Yeast strains (factor 2)									
Lavin V1116	26.33 ns	27.01 ns	8.46 ns	6.30 ns	11.54 a	3.90 a	2.83 b	179.03 a	2.09 ns
Fermivin	26.89	26.61	8.54	6.36	11.29 b	3.83 b	2.99 a	169.86 b	2.32
Fermivin PDM	26.96	25.43	8.19	6.26	11.57 a	3.90 a	2.75 c	168.29 b	2.17

Means within the same column with different common letters differ significantly by DMRT; * = $p<0.05$; ns= non-significant

[1] Total titrable acidity shown in the form of citric acid (g/l)

[2] Total phenolic compounds shown in the form of Gallic acid equivalent (mg/100 ml of wines)

[3] Antioxidant index must be ≥1; if <1 shown then there is no antioxidative activity.

[4] Internal colors of Krachai-Dam rhizomes used as raw materials had 3 levels: Phurua-10 'Rom-Klao' cultivar with a dark purple color, Phurua-5 'Nam-Juang' with a purple color and Phurua-12 'Kheg-Noi #2' with a pale purple color.

When 2-factor combinations (Table 4.2) were considered, there were significant relations between the 2 factors studied related to qualities of wines: TSS, alcohol percentage, pH, TA and b* (6.00-6.67°Brix, 10.93-11.73%, 3.80-4.03, 2.50-3.20 g/l and 3.37-11.84 respectively)

The most important qualities (TP and AOI) of wines were considered. It was found that the treatment combination of 'Rom-Klao' cultivar and Lalvin V1116 yeast strain had the highest TP and AOI (225.01 mg GAE/ 100 ml of wines and 3.28 respectively) which were significantly higher than the treatment combination of 'Rom-Klao' cultivar and Fermivin yeast strain (221.29 mg GAE/ 100 ml of wines and 3.11) and Fermivin PDM yeast strains (211.79 mg GAE/ 100 ml of wines and 2.82) respectively.

Table 4.2: Effects of factor combinations in experiment 1.2 on Krachai-Dam honey wine qualities.

Factor combinations			Physical and chemical qualities of wines								
Yeast strains	Krachai-Dam cultivars[4]	Tr no.	Wine color L*	Wine color a*	Wine color b*	Total soluble solid (°Brix)	Alcohol (% v/v)	pH	Total titrable acidity[1](g/l)	Total phenolic compounds[2]	Anti-oxidant index[3]
Lalvin VI116	Rom-Klao	37	17.14 ns	32.75 ns	3.37 c	6.47 a	11.53 bc	3.80 d	3.01 bc	225.08 ns	3.28 ns
	Nam-Juang	43	32.69	20.06	10.29 a	6.00 c	11.50 bc	3.87 cd	2.59 d	143.08	1.35
	Kheg-Noi#2	49	29.17	26.21	11.72 a	6.43 ab	11.60 b	4.03 a	2.89 c	168.92	1.67
Fermivin	Rom-Klao	38	16.61	34.29	4.75 bc	6.67 a	11.50 bc	3.80 d	3.20 a	221.29	3.11
	Nam-Juang	44	33.81	20.85	10.82 a	6.20 bc	10.93 d	3.80 d	2.71 d	135.63	1.94
	Kheg-Noi#2	50	30.25	24.69	10.04 a	6.20 bc	11.43 c	3.90 bc	3.08 ab	152.67	1.90
Fermivin PDM	Rom-Klao	39	17.17	32.72	5.39 bc	6.03 c	11.50 bc	3.90 bc	2.71 d	211.79	2.82
	Nam-Juang	45	32.92	22.77	11.84 a	6.13 c	11.73 a	3.83 cd	2.66 d	137.79	2.03
	Kheg-Noi#2	51	30.80	20.79	7.34 b	6.60 a	11.47 bc	3.97 b	2.87 c	155.29	1.64
	CV %		7.95	9.60	18.17	21.59	1.13	0.96	2.74	3.36	15.42

Means within the same column with different common letters differ significantly by DMRT; * = $p<0.05$; ns= non-significant

[1] Total titrable acidity shown in the form of citric acid (g/l)

[2] Total phenolic compounds shown in the form of Gallic acid equivalent (mg/100 ml of wines)

[3] Antioxidant index must be ≥1; if <1 shown then there is no antioxidative activity.

[4] Internal colors of Krachai-Dam rhizomes used as raw materials had 3 levels: Phurua-10 'Rom-Klao' cultivar with a dark purple color, Phurua-5 'Nam-Juang' with a purple color and Phurua-12 'Kheg-Noi #2' with a pale purple color.

4.2. Effects of Krachai-Dam cultivars, types of honey and proportion of rhizomes in must on wine qualities.

Physical and chemical qualities of wines included color (L*, a* and b*), total soluble solids (TSS), alcohol percentages, pH, total titrable acidities (TA), total phenolic compounds (TP) and antioxidant indexes (AOI) in each factor as shown in Table 4.3. Proportion of rhizomes in must (factor 1): There were significant differences in all parameters studied. TP, AOI and a* of wines increased proportionally with the amount of rhizomes in must, whereas L* and b* decreased. Types of honey (factor 2): There were significant difference in all parameters studied except only AOI and a*. Sab-Seua wines had the highest TP and the lowest L* and b*. Krachai-Dam cultivars (factor 3): There were significant difference in all parameters studied except the TSS and TA. 'Rom-Klao' wines had the highest TP, AOI and a*, and the lowest L* and b*.

When each pair of factors combination (Table 4.4) was considered, the effects of 2-factor combinations from 3 factors were studied, which were proportion of rhizomes in must (factor 1), types of honey (factor 2) and Krachai-Dam cultivars (factor 3). There were significant relationships between the 2-factor combination of proportion of rhizomes in must (factor 1) and types of honey (factor 2) in 4 parameters of wine qualities studied, which were TSS, alcohol percentage, pH and TA. As for TSS, the combination with 5% w/w of rhizomes in must and Sab-Suea honey gave the highest TSS (6.88°Brix), whereas the combination between 15% w/w of rhizomes in must and Lychee honey gave the lowest (5.44 °Brix). As for alcohol percentage, the combination with 10% w/w of rhizomes in must and Lychee honey gave the highest percentage (11.64%) which was nearly the same with 5 and 7.5% w/w of rhizomes in must and Lychee honey (11.61 and 11.63% respectively), whereas the combination with 15% w/w of rhizomes in must and Sab-Suea honey and between 15% w/w of rhizomes and Longan honey gave the lowest (10.54 and 10.60% respectively). As for pH, the combination with 15% w/w of rhizomes in must and Lychee honey gave the highest pH (4.08), whereas the combination with 5% w/w of rhizomes and Sab-Suea honey gave the lowest (3.76). As for TA, the combination with 15% w/w of rhizomes in must and Longan honey gave the highest TA (5.06g/l),

whereas the combination of 5 and 7.5% w/w of rhizomes and all types of honey gave the lowest (2.12-2.53 g/l).

Table 4.3 Effects of Krachai-Dam cultivars, types of honey and proportion of rhizomes in must on wine qualities.

Factors	Physical and chemical qualities of wines								
	Wine color			Total soluble solids (°Brix)	Alcohol (% v/v)	pH	Total titrable acidity[1](g/l)	Total phenolic compounds[2]	Anti-oxidant index[3]
	L*	a*	b*						
Proportion of rhizomes in must (factor 1)									
5%	34.07 a	21.57 c	8.62 a	6.42 a	11.28 b	3.80 d	2.26 c	147.25 e	1.26 d
7.5%	25.71 b	27.52 b	7.70 b	6.36 a	11.30 b	3.97 b	2.44 c	181.92 d	1.90 c
10%	19.12 c	31.45 a	5.39 c	6.48 a	11.46 a	4.03 a	2.42 c	214.17 c	2.25 b
12.5%	15.63 d	31.93 a	1.97 d	6.48 a	11.31 b	3.91c	3.96 b	285.00 a	3.17 a
15.0%	16.20 d	31.88 a	1.88 d	5.68 b	10.69 c	3.93 bc	4.24 a	279.81 b	2.98 a
Types of honey (factor 2)									
Longan	22.42 a	28.91 ns	5.57 a	6.25 b	11.20 b	3.94 a	3.24 a	205.39 b	2.28 ns
Lychee	22.51 a	29.09	4.69 b	6.10 c	11.48 a	3.97 a	2.85 b	204.95 b	2.23
Sab-Seua	21.50 b	28.60	5.07 b	6.49 a	10.96 c	3.87 b	3.10 a	217.36 a	2.42
Krachai-Dam cultivars[4] (factor 3)									
Rom-Klao	17.83 c	30.38 a	2.13 c	6.30 ns	11.27 b	3.92 ns	2.97 b	233.56 a	2.57 a
Nam-Juang	22.81 b	28.85 b	5.64 b	6.23	11.14 b	3.94	2.98 b	208.74 b	2.25 b
Kheg-Noi#2	25.81 a	27.37 c	7.56 a	6.32	11.21 a	3.92	3.24 a	185.40 c	2.11 b

Means within the same column with different common letters differ significantly by DMRT; * = $p<0.05$; ns=non-significant

[1] Total titrable acidity shown in the form of citric acid (g/l)

[2] Total phenolic compounds shown in the form of Gallic acid equivalent (mg/100 ml of wines)

[3] Antioxidant index must be ≥1; if <1 shown then there is no antioxidative activity.

[4] Internal colors of Krachai-Dam rhizomes used as raw materials had 3 levels: Phurua-10 'Rom-Klao' cultivar with a dark purple color, Phurua-5 'Nam-Juang' with a purple color and Phurua-12 'Kheg-Noi #2' with a pale purple color.

As for the effects of 2-factor combination between proportion of rhizomes in must (factor 1) and Krachai-Dam cultivars (factor 3) on wine qualities, it was found that there were significant relations between the 2 factors studied in all parameters studied. As for wine color, L*, the combination with 5% w/w of rhizomes and 'Kheg-Noi#2' and 'Nam-Juang' cultivars gave the highest L* (36.77 and 35.05, respectively) whereas 12.5 and 15.0% w/w of rhizomes and 'Rom-Klao' cultivar gave the lowest ones (11.92 and 11.87 respectively). As for a*, the combinations with 7.5% w/w of rhizomes and 'Rom-Klao' cultivars, 12.5 and 15% w/w of rhizomes and 'Nam-Juang' and 'Kheg-Noi#2' cultivars gave the highest a* (32.40, 33.00, 32.18, 33.23, 31.56, 32.41, and 32.02 respectively), whereas the combinations with 5% w/w of rhizomes and 'Nam-Juang' and 'Kheg-Noi#2' cultivars gave the lowest ones (20.50 and 19.91 respectively). As for b*, the combinations with 5% w/w of rhizomes and 'Nam-Juang' cultivar, 7.5% w/w of rhizomes and 'Nam-Juang' and 'Kheg-Noi#2' cultivars and 10% w/w of rhizomes and 'Kheg-Noi#2' cultivar gave the highest b* (8.70, 8.91, 8.35 and 9.01 respectively), whereas the combinations with 12.5 and 15.0% w/w of rhizomes and 'Rom-Klao' cultivar gave the lowest ones (-2.51 and -2.12, respectively). As for TSS, the combinations with 12.5% w/w of rhizomes and 'Rom-Klao' cultivar and 5% w/w of rhizomes and 'Kheg-Noi#2' cultivar gave the highest TSS (6.91 and 6.87°Brix), whereas the combination with 15% w/w of rhizomes and 'Kheg-Noi#2' cultivar gave the lowest one (5.42°Brix). As for alcohol percentage, the combination with 10% w/w of rhizomes and 'Nam-Juang' cultivar gave the highest percentage (11.59%), whereas the combinations with 15% w/w of rhizomes and 'Rom-Klao' and 'Nam-Juang' cultivars gave the lowest (10.57 and 10.64%, respectively); pH the combination with 10% w/w of rhizomes and 'Nam-Juang' cultivar gave the highest pH (4.04), whereas the combination with 5% w/w of rhizomes and 'Rom-Klao' cultivar gave the lowest ones (3.68). As for TA, the

combination with 12.5% w/w of rhizomes and 'Nam-Juang' and Kheg-Noi#2' cultivars and 15.0% w/w of rhizomes and all cultivars gave the highest TA (3.90-4.47 g/l), whereas the combinations between 5, 7.5 and 10% w/w of rhizomes and all cultivars gave the lowest ones (2.12-2.71 g/l). As for TP, the combination with 12.5% w/w of rhizomes and 'Rom-Klao' cultivars gave the highest TP (339.71 mg/100 ml), whereas the combinations with 5% w/w of rhizomes and 'Kheg-Noi#2' cultivars gave the lowest one (133.76 mg/ 100 ml). As for AOI, the combination with 12.5% w/w of rhizomes and 'Rom-Klao' cultivar gave the highest AOI (3.59), whereas the combinations with 5% w/w of rhizomes and all cultivars and 7.5% w/w of rhizomes and 'Kheg-Noi#2' cultivar gave the lowest ones (1.15-1.44).

As for the effects of 2-factor combination between types of honey (factor 2) and Krachai-Dam cultivars (factor 3) on wine qualities, it was found that there were significant relations between the 2 factors studied in 4 parameters, which were alcohol percentage and wine color L*, a and b*. As for alcohol percentage, the combination of Lychee honey and 'Rom-Klao' cultivar rendered the highest percentage (11.64%), whereas the combinations of Sab-Suea honey and 'Nam-Jung' and 'Kheg-Noi#2' rendered the lowest ones (10.89 and 10.95% respectively). As for wine color, L*, the combinations of 'Kheg-Noi#2' cultivar and all types of honey rendered the highest L* (25.11-27.15), whereas the combinations of 'Rom-Klao' cultivar and Longan and Sab-Suea honey rendered the lowest ones (17.89 and 17.10, respectively). As for a*, the combinations of 'Rom-Klao' cultivar and Longan and Lychee honey rendered the highest a* (30.80 and 30.79 respectively), whereas the combination of 'Kheg-Noi#2' cultivar and Sab-Suea honey rendered the lowest one (26.45). As for b*, the combinations of 'Kheg-Noi#2' cultivar and Longan and Sab-Suea honey rendered the highest b* (8.29 and 7.67 respectively), whereas the combination of 'Rom-Klao' cultivar and Sab-Suea honey rendered the lowest one (1.27).

When 3-factor combinations were considered (Table 4.5), there were significant relations among the 3 factors studied in qualities of wines: TSS, alcohol percentage, pH and TA (5.13-7.57°Brix, 10.37-12.00 %, 3.70-4.27 and 1.52-5.65 g/l respectively).

As the main purpose of Krachai-Dam honey wines consumption was to produce herbal wines, the most important qualities considered were the TP and AOI. It was found that the treatment combination of 'Rom-Klao' cultivar with 15%w/w of rhizomes in must, Sab-Suea honey and Lalvin V1116 yeast strain, had the highest AOI (3.83) which was not significantly higher for treatment combination of 'Rom-Klao' cultivar, 12.5%w/w of rhizomes in must, Lychee honey and Lalvin V1116 yeast strain (3.76) and the combination of 'Rom-Klao' cultivar, 12.5%w/w of rhizomes in must, Sab-Suea honey and Lalvin V1116 yeast strain (3.60) respectively. Whereas the treatment combination of 'Rom-Klao' cultivar, 12.5 and 15%w/w of rhizomes in must, Longan honey and Lalvin V1116 yeast strain and the combination of 'Rom-Klao' cultivar, 12.5%w/w of rhizomes in must, Sab-Suea honey and Lalvin V1116 yeast strain had the highest TP (342.50 340.42 and 341.38 mg GAE/ 100 ml of wines respectively).

Table 4.4 Effects of each pair of 2-factor combinations in experiment 1.1 comparing the 3 factors, i.e. proportion of rhizomes in must, type of honey and Krachai-Dam cultivars.

Factors		Physical and chemical qualities of wines								
		Wine color			Total soluble solid (°Brix)	Alcohol (% v/v)	pH	Total titrable acidity[1](g/l)	Total phenolic compounds[2]	Anti-oxidant index[3]
		L*	a*	b*						
Proportion of rhizomes	**Type of honey**									
5%	Longan	33.82 ns	21.37 ns	8.79 ns	6.32 bcde	11.33 bc	3.88 defg	2.12 d	139.55 h	1.28 ns
	Lychee	35.12	21.81	8.30	6.07 def	11.61 a	3.77 gh	2.18 d	142.27 h	1.22
	Sab-seua	33.27	21.52	8.78	6.88 a	10.90 f	3.76 h	2.47 d	159.94 g	1.28
7.5%	Longan	26.14	26.82	7.62	6.10 cdef	11.27 c	4.01 abc	2.43 d	173.26 fg	1.91
	Lychee	26.77	27.05	7.11	6.36 bcde	11.63 a	3.99 abcd	2.39 d	178.50 ef	2.05
	Sab-seua	24.23	28.70	8.37	6.63 ab	11.01 def	3.90 cdef	2.52 d	194.00 de	1.73
10%	Longan	19.62	31.64	6.11	6.43 abcd	11.57 ab	4.06 ab	2.41 d	207.21 d	2.16
	Lychee	18.80	32.09	4.67	6.41 abcde	11.64 a	4.07 ab	2.33 d	207.03 d	2.13
	Sab-seua	18.95	30.61	5.38	6.59 abc	11.18 cde	3.96 bcd	2.53 d	228.26 c	2.47
12.5%	Longan	16.02	32.14	2.36	6.49 abcd	11.21 cd	3.96 bcd	4.20 b	287.42 ab	3.15
	Lychee	15.85	32.43	1.89	6.24 bcde	11.57 ab	3.97 abcd	3.52 c	275.58 ab	3.08
	Sab-seua	15.03	31.22	1.65	6.70 ab	11.17 cde	3.81 efgh	4.16 b	292.00 a	3.29
15%	Longan	16.52	32.61	2.98	5.92 ef	10.60 g	3.80 fgh	5.06 a	285.33 ab	2.91
	Lychee	16.06	32.06	1.46	5.44 g	10.93 f	4.08 a	3.83 bc	284.07 ab	2.69
	Sab-seua	16.03	30.96	1.19	5.67 fg	10.54 g	3.92 cde	3.82 bc	270.03 b	3.34
Proportion of rhizomes	**Krachai-Dam cultivars[4]**									
5%	Rom-Klao	30.39 b	24.29 c	7.95 ab	6.53 abc	11.47 abc	3.68 e	2.43 c	156.62 ij	1.20 e
	Nam-Juang	35.05 a	20.50 d	8.70 a	5.87 e	11.13 cde	3.87 cd	2.22 c	151.38 j	1.15 e
	Kheg-Noi#2	36.77 a	19.91 d	9.23 a	6.87 a	11.24 bcd	3.86 d	2.12 c	133.76 k	1.43 e
7.5%	Rom-Klao	20.31 e	32.40 a	5.83 c	5.96 de	11.34 abc	3.98 abcd	2.40 c	189.99 h	2.20 d
	Nam-Juang	27.48 c	25.95 c	8.91 a	6.47 abc	11.36 abc	3.94 abcd	2.43 c	190.49 h	2.05 d
	Kheg-Noi#2	29.33 bc	24.23 c	8.35 a	6.67 ab	11.21 bcd	3.98 abcd	2.50 c	165.29 i	1.44 e
10%	Rom-Klao	14.68 g	33.00 a	1.53 f	6.31 bcd	11.44 abc	4.03 ab	2.39 c	236.53 f	2.66 c
	Nam-Juang	19.23 ef	32.18 a	5.64 cd	6.60 ab	11.59 a	4.04 a	2.17 c	210.60 g	2.10 d
	Kheg-Noi#2	23.47 d	29.16 b	9.01 a	6.52 abc	11.36 abc	4.00 abc	2.71 c	195.38 h	2.00 d
12.5%	Rom-Klao	11.92 h	31.01 ab	-2.51 g	6.91 a	11.54 ab	3.99 abcd	3.31 b	339.71 a	3.59 a
	Nam-Juang	14.71 g	33.23 a	1.59 f	6.41 bc	11.00 de	3.87 cd	4.18 a	280.40 c	2.99 bc
	Kheg-Noi#2	20.27 e	31.56 a	6.82 bc	6.11 cde	11.40 abc	3.88 cd	4.39 a	234.89 f	2.94 bc
15%	Rom-Klao	11.87 h	31.21 ab	-2.12 g	5.80 ef	10.57 f	3.94 abcd	4.33 a	321.90 b	3.20 ab
	Nam-Juang	17.56 f	32.41 a	3.35 e	5.81 ef	10.64 f	3.96 abcd	3.90 a	268.19 d	3.01 bc
	Kheg-Noi#2	19.19 ef	32.02 a	4.40 de	5.42 f	10.87 ef	3.90 bcd	4.47 a	249.33 e	2.74 bc
Type of honey	**Krachai-Dam cultivars[4]**									
Longan	Rom-Klao	17.89 c	30.80 a	2.55 cd	6.30 ns	11.14 bcd	3.94 ns	3.26 ns	233.36 ab	2.49 ns
	Nam-Juang	22.23 abc	29.49 ab	5.87 ab	6.13	11.16 bcd	3.94	3.27	198.51 cd	2.21
	Kheg-Noi#2	27.15 a	26.45 b	8.29 a	6.33	11.29 bc	3.94	3.21	184.28 d	2.14
Lychee	Rom-Klao	18.51 bc	30.79 a	2.59 cd	6.19	11.64 a	3.93	2.78	229.98 ab	2.58
	Nam-Juang	23.94 ab	28.09 ab	4.75 bc	6.10	11.38 ab	4.01	2.67	205.10 bcd	2.13
	Kheg-Noi#2	25.11 a	28.47 ab	6.72 ab	6.03	11.41 ab	3.97	3.09	179.78 d	1.99
Sab-seua	Rom-Klao	17.10 c	29.65 ab	1.27 d	6.42	11.04 cd	3.90	2.88	237.35 a	2.64
	Nam-Juang	22.25 abc	28.97 ab	6.29 ab	6.47	10.89 d	3.85	3.00	222.60 abc	2.44
	Kheg-Noi#2	25.16 a	27.20 ab	7.67 a	6.59	10.95 d	3.85	3.42	192.14 d	2.19
CV		8.23	7.72	21.86	4.96	1.35	2.29	15.69	12.78	20.35

Means within the same column with different common letters differ significantly by DMRT; * = $p<0.05$; ns=non-significant

[1] Total titrable acidity shown in the form of citric acid (g/l)

[2] Total phenolic compounds shown in the form of Gallic acid equivalent (mg/100 ml of wines)

[3] Antioxidant index must be ≥1; if <1 shown then there is no antioxidative activity.

[4] Internal colors of Krachai-Dam rhizomes used as raw materials had 3 levels: Phurua-10 'Rom-Klao' cultivar with a dark purple color, Phurua-5 'Nam-Juang' with a purple color and Phurua-12 'Kheg-Noi #2' with a pale purple color.

Table 4.5 Effects of 3-factor combinations in experiment 1.1 on Krachai-Dam honey wine qualities.

Factor combinations				Physical and chemical qualities of wines									
Proportion of rhizomes in must	Type of honey	Krachai-Dam cultivars[4]	Treatment no.	Wine color			Total soluble solids (°Brix)	Alcohol (%)	pH	Total titrable acidity[1](g/l)	Total phenolic compounds[2]	Anti-oxidant index[3]
				L*	a*	b*						
5%w/w	Longan	Rom-Klao	55	30.57 ns	24.02 ns	8.08 ns	6.40 defghi	11.50 cdef	3.70 h	2.57 hijklmno	151.23 ns	1.24 ns
		Nam-Juang	64	34.29	20.79	8.64	5.60 klmn	11.23 fghi	3.97 bcdef	2.26 lmnop	126.41	1.09
		Kheg-Noi#2	73	36.61	19.29	9.65	6.97 bcd	11.27 efghi	3.97 bcdef	1.52 p	141.00	1.50
	Lychee	Rom-Klao	56	31.42	25.54	8.91	6.20 efghijk	11.77 abc	3.67 h	2.24 mnop	147.33	1.18
		Nam-Juang	65	37.75	18.95	7.72	5.93 hijklm	11.53 cde	3.83 efgh	2.12 nop	158.00	1.16
		Kheg-Noi#2	74	36.18	20.95	8.29	6.07 hijklm	11.53 cde	3.80 fgh	2.17 nop	121.48	1.31
	Sab-scua	Rom-Klao	57	29.17	23.32	6.85	7.00 bcd	11.13 ijkl	3.67 h	2.50 ijklmno	171.13	1.18
		Nam-Juang	66	33.11	21.76	9.73	6.07 hijklm	10.63 nop	3.80 fgh	2.26 lmnop	169.73	1.19
		Kheg-Noi#2	75	37.53	19.49	9.75	7.57 a	10.93 jklm	3.80 fgh	2.66 hijklmno	138.79	1.48
7.5 % w/w	Longan	Rom-Klao	58	19.10	32.80	5.29	5.87 ijklm	11.10 ijkl	4.00 bcde	2.43 jklmnop	188.17	2.05
		Nam-Juang	67	26.89	26.71	9.20	6.20 efghijk	11.50 cdef	4.00 bcde	2.47 ijklmnop	182.58	2.28
		Kheg-Noi#2	76	32.43	20.95	8.38	6.23 efghil	11.20 ghij	4.03 bcd	2.40 klmnop	149.04	1.39
	Lychee	Rom-Klao	59	22.03	31.41	5.79	5.80 ijklm	11.93 ab	4.03 bcd	2.36lmnop	180.71	2.81
		Nam-Juang	68	30.19	23.20	7.95	6.20 efghijk	11.53 cde	3.93 cdef	2.52 hijklmno	180.75	1.90
		Kheg-Noi#2	77	28.07	26.54	7.58	7.07 abc	11.43 defgh	4.00 bcde	2.29 lmnop	174.04	1.45
	Sab-scua	Rom-Klao	60	19.81	33.00	6.43	6.20 efghijk	11.00 ijklm	3.90 defg	2.43 jklmno	201.08	1.74
		Nam-Juang	69	25.37	27.93	9.60	7.00 bcd	11.03 ijklm	3.90 defg	2.31 lmnop	208.13	1.97
		Kheg-Noi#2	78	27.50	25.18	9.09	6.70 bcdefg	11.00 ijklm	3.90 defg	2.82 ghijklmno	172.79	1.49
10% w/w	Longan	Rom-Klao	61	15.11	33.17	2.21	6.03 hijklm	11.47 cdefg	4.13 ab	2.31 lmnop	226.63	2.72
		Nam-Juang	70	19.02	32.47	6.26	6.53 bcdefgh	11.57 cd	4.07 bcd	2.24 mnop	213.88	1.90
		Kheg-Noi#2	79	24.73	29.27	9.86	6.73 bcdefg	11.67 bcd	3.97 bcdef	2.68 hijklmno	181.13	1.87
	Lychee	Rom-Klao	62	13.99	32.84	0.99	6.40 defghi	11.63 cd	4.00 bcde	2.45 jklmnop	239.96	2.42
		Nam-Juang	71	18.66	32.65	4.48	6.77 bcdef	11.67 bcd	4.10 bc	2.17 nop	199.83	1.96
		Kheg-Noi#2	80	23.75	30.79	8.55	6.07 hijklm	11.63 cd	4.10 bc	2.38 lmnop	181.29	2.00
	Sab-scua	Rom-Klao	63	14.94	33.00	1.38	6.50 cdefgh	11.23 fghi	3.97 bcdef	2.40 klmnop	243.00	2.83
		Nam-Juang	72	20.00	31.40	6.17	6.50 cdefgh	11.53 cde	3.97 bcdef	2.10 op	218.08	2.45
		Kheg-Noi#2	81	21.92	27.42	8.60	6.77 bcdef	10.77 mno	3.93 cdef	3.08 fghijklmn	223.71	2.12
12.5% w/w	Longan	Rom-Klao	163	12.23	31.69	-1.93	7.13 ab	11.17 hijk	3.97 bcdef	3.36 fghij	342.50	3.42
		Nam-Juang	169	14.69	33.87	1.63	6.13 ghijkl	10.93 jklm	3.97 bcdef	4.55 bcde	279.88	2.83
		Kheg-Noi#2	175	21.13	30.84	7.37	6.20 efghijk	11.53 cde	3.93 cdef	4.69 bcde	239.88	3.19
	Lychee	Rom-Klao	164	12.46	32.21	-1.66	6.80 bcde	12.00 a	4.00 bcde	3.41 fghi	335.25	3.76
		Nam-Juang	170	15.46	33.21	1.69	6.13 ghijkl	11.17 hijk	3.93 cdef	3.34 fghijk	263.13	2.82
		Kheg-Noi#2	176	19.63	31.89	5.63	5.80 ijklm	11.53 cde	3.97 bcdef	3.80 def	228.38	2.65
	Sab-scua	Rom-Klao	165	11.07	29.13	-3.94	6.80 bcde	11.47 cdefg	4.00 bcde	3.17 fghijklm	341.38	3.60
		Nam-Juang	171	13.99	32.60	1.44	6.97 bcd	10.93 klmn	3.70 h	4.64 bcd	298.21	3.31
		Kheg-Noi#2	177	20.04	31.94	7.46	6.33 efghij	11.13 ijkl	3.73 gh	4.67 bcd	236.42	2.97
15% w/w	Longan	Rom-Klao	166	12.45	32.31	-0.90	6.07 hijklm	10.47 p	3.90 defg	5.65 a	340.42	3.04
		Nam-Juang	172	16.26	33.62	3.64	6.17 fghijk	10.57 op	3.70 h	4.81 b	261.92	2.94
		Kheg-Noi#2	178	20.86	31.91	6.19	5.53 lmn	10.77 mno	3.80 fgh	4.74 bc	253.67	2.76
	Lychee	Rom-Klao	167	12.64	31.54	-1.08	5.73 jklm	10.87 lmn	3.97 bcdef	3.45 fgh	329.29	2.72
		Nam-Juang	173	17.64	32.46	1.90	5.47 mn	11.00 ijklm	4.27 a	3.22 fghijkl	270.92	2.79
		Kheg-Noi#2	179	17.91	32.19	3.57	5.13 n	10.93 jklm	4.00 bcde	4.80 b	252.00	2.55
	Sab-scua	Rom-Klao	168	10.51	29.79	-4.39	5.60 klmn	10.37 p	3.97 bcdef	3.90 cdef	296.00	3.83
		Nam-Juang	174	18.79	31.14	4.52	5.80 ijklm	10.37 p	3.90 defg	3.69 efg	271.75	3.29
		Kheg-Noi#2	180	18.79	31.95	3.44	5.80 klmn	10.90 klmn	3.90 defg	3.87 cdef	242.33	2.90
CV %				8.23	7.72	21.86	4.96	1.35	2.29	15.69	12.78	20.35

Means within the same column with different common letters differ significantly by DMRT; * = $p<0.05$; ns= non-significant

[1] Total titrable acidity shown in the form of citric acid (g/l)

[2] Total phenolic compounds shown in the form of Gallic acid equivalent (mg/100 ml of wines)

[3] Antioxidant index must be ≥1; if <1 shown then there is no antioxidative activity.

[4] Internal colors of Krachai-Dam rhizomes used as raw materials had 3 levels: Phurua-10 'Rom-Klao' cultivar with a dark purple color, Phurua-5 'Nam-Juang' with a purple color and Phurua-12 'Kheg-Noi #2' with a pale purple color.

4.3. Grouping of the treatment combinations

The selection of high quality Krachai-Dam wine processing must consider not only gave the highest TP and AOI, but also should receive the highest acceptable sensory evaluation scores of panelists. The limitation of sensory evaluation was that the number of samples should not exceed 5, while our sample had 54. Thus this study needed to use an unweighted pair group method cluster analysis (UPGMA) to group these samples in accordance with 9 quality parameters. The result is shown in a dendrogram (Figure 2). The Krachai-Dam honey wines processes can be classified into 5 main groups as follows;

Group A can be classified into 5 subgroups which are subgroup A.1 consisting of 5 treatment combinations: 37, 38, 176, 39 and 179; subgroup A.2 consisting of 2 combinations: 58 and 60; subgroup A.3 consisting of 3 combinations: 61, 62 and 63; subgroup A.4 consisting of 5 combinations: 70, 71, 72, 59 and 80; and subgroup A.5 consisting of 1 combinations: 173.

Group B can be classified into 4 subgroups which are subgroup B.1 consisting of 3 treatment combinations: 172, 177 and 171; subgroup B.2 consisting of 2 combinations: 58 and 60; subgroup B.3 consisting of 4 combinations: 178, 180, 174 and 179; and subgroup B.4 consisting of 2 combinations: 163, 164 and 165.

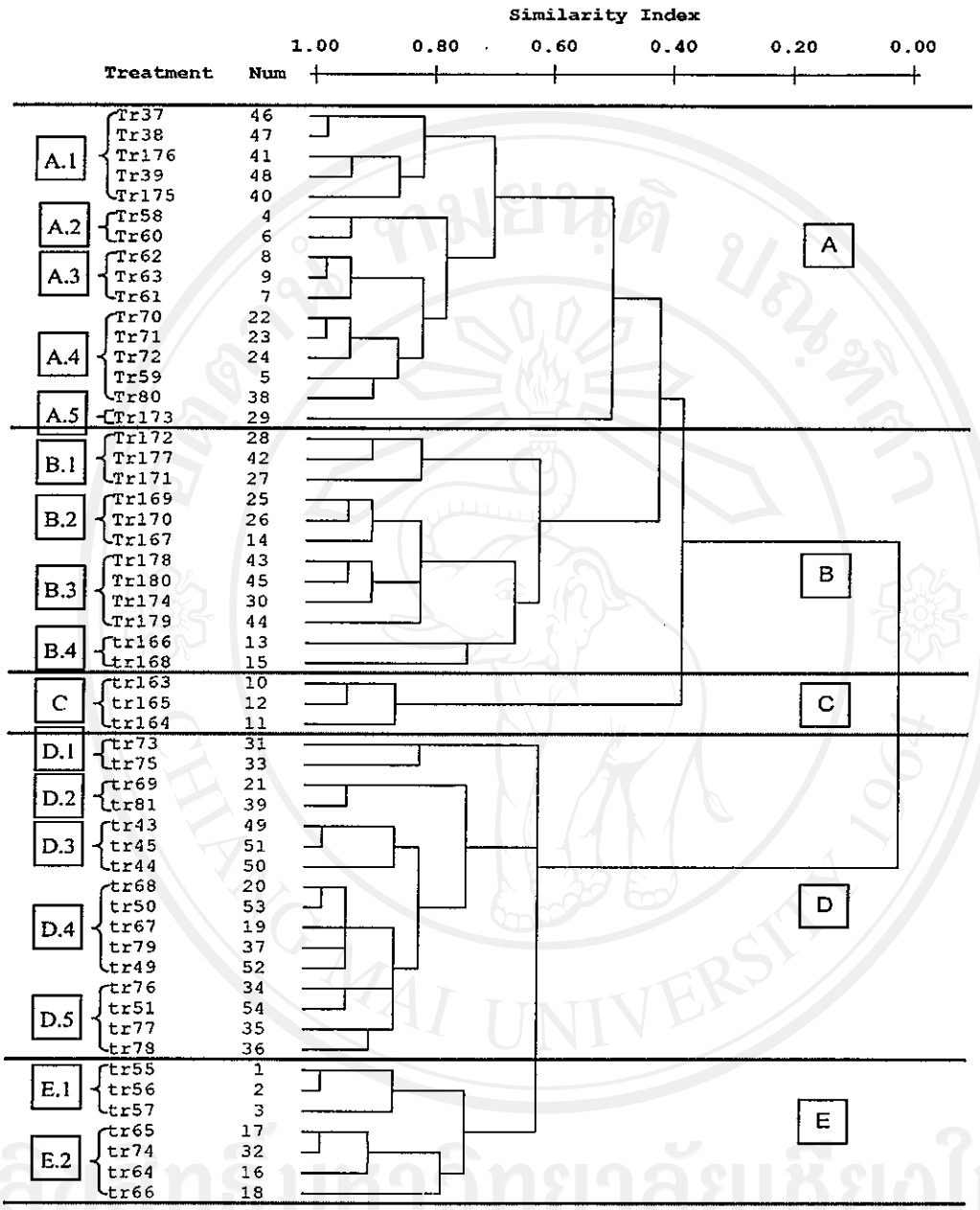

Figure 4.1 Dendrogram obtained from 9 physical and chemical characters of Krachai-Dam Honey wine using UPGMA.

Group C has 1 subgroup consisting of 3 treatment combinations: 163, 164 and 165.

Group D can be classified into 5 subgroups which are subgroup D.1 consisting of 2 treatment combinations: 73 and 75; subgroup D.2 consisting of 2 combinations: 69 and 81; subgroup D.3 consisting of 3 combinations: 43, 44 and 45; subgroup D.4 consisting of 5 combinations: 68, 50, 67, 79 and 49; and subgroup D.5 consisting of 4 combinations: 76, 51, 77, and 78.

Group E can be classified into 2 subgroups which are subgroup E.1 consisting of 3 treatment combinations: 55, 56 and 57; and subgroup E.2 consisting of 4 combinations: 65, 74, 64 and 66.

4.4. Sensory evaluation

4.4.1 Sensory evaluation in round 1

Sensory testing by at least 15-trained panelists was obtained and analyzed for selecting the most optimal Krachai-Dam honey wine process that rendered the highest total appreciation scores of each group (Table 4.6). The results were as follows:

Group A had a selected treatment in each subgroup, which were treatment combination number 39 (total appreciation scores of 65.59) in subgroup A.1, number 60 (74.06) in subgroup A.2, number 61 (66.29) in subgroup A.3 with non-significance, and number 71 (65.13) in subgroup A.4.

Group B had a selected treatment in each subgroup, which were treatment combination number 171 (total appreciation scores of 48.47) in subgroup B.1 with non-significance, number 167 (58.60) in subgroup B.2 with non-significance, number 178 (53.38) in subgroup B.3 with non-significance, and number 168 (53.59) in subgroup B.4.

Group D had a selected treatment in each subgroup, which were treatment combination number 73 (total appreciation scores of 63.24) in subgroup D.1, number 69 (65.50) in subgroup D.2, number 45 (57.75) in subgroup D.3, number 79 (62.06) in subgroup D.4, and number 77 (71.31) in subgroup D.5.

Group E had a selected treatment in each subgroup, which were treatment combination number 55 (total appreciation scores of 74.46) in subgroup E.1, and number 66 (61.56) in subgroup E.2.

Table 4.6 Wine appreciation chart of Krachai-Dam honey wines by sensory evaluation of 15-23 panelists (round 1).

Group	Treatment	Wine appreciation scores							
		Appearance (10)	Color (5)	Varietal aroma &bouquet (30)	Flavor (15)	Acidity (10)	Defect (10)	General quality (20)	Total (100)
A.1	175	5.88 c	1.47 c	14.12 ns	6.18 c	5.06 ns	4.12 b	8.71 b	45.53 b
	176	7.88 a	3.35 b	18.71	8.47 b	5.88	5.41 ab	11.53 a	61.24 a
	37	6.24 bc	3.47 ab	17.29	8.82 ab	6.59	6.24 a	12.47 a	61.12 a
	38	7.06 ab	3.76 ab	20.12	8.29 b	5.76	6.47 a	11.06 a	62.53 a
	39	8.00 a	4.06 a	17.29	10.24 a	6.59	6.24 a	13.18 a	65.59 a
CV (%)		23.07	27.57	37.20	26.46	30.52	36.60	28.17	19.54
A.2	58	7.56 ns	3.88 ns	21.18 ns	9.18 ns	5.65 b	6.59 ns	12.24 b	66.35 b
	60	8.35	3.82	23.65	10.24	6.82 a	6.82	14.35 a	74.06 a
CV (%)		17.61	7.87	17.78	23.10	18.02	19.55	18.61	8.74
A.3	61	7.06 ns	3.76 ns	20.12 ns	9.35 ns	6.00 ns	6.82 ns	13.18 ns	66.29 ns
	62	6.94	3.88	20.82	9.53	5.53	6.12	11.76	64.59
	63	7.41	4.06	20.47	8.47	5.18	6.00	11.29	62.88
CV (%)		12.29	11.64	28.64	32.26	28.30	24.18	25.71	18.77
A.4	59	6.63 bc	3.69 a	15.75 b	6.75 b	5.13 ns	4.75 ns	9.25 ns	51.94 bc
	70	4.38 d	2.56 b	14.63 b	6.94 b	5.13	4.25	8.50	46.38 c
	71	8.25 a	3.94 a	22.13 a	9.19 a	5.38	5.50	10.75	65.13 a
	72	5.50 cd	2.81 b	15.38 b	7.13 b	5.75	5.13	9.50	51.19 bc
	80	7.38 ab	3.44 a	16.50 b	7.88 ab	5.50	5.50	10.50	56.69 b
CV (%)		25.10	22.58	35.66	31.88	30.38	31.75	30.20	20.81
B.1	171	5.41 ns	3.47 a	17.56 a	5.47 ns	4.71 ns	4.47 ns	7.29 ns	48.47 ns
	172	5.41	1.76 c	10.24 b	4.94	4.12	3.41	7.29	37.18
	177	4.94	2.53 b	15.53 a	6.00	4.94	4.71	7.29	45.94
CV (%)		25.23	29.88	48.38	44.37	43.44	42.89	46.18	30.82

#Means within the same column with different common letters differ significantly by DMRT; * = $p<0.05$; ns= non-significant

Table 4.6 (continue)

Group	Treatment	Wine appreciation scores							
		Appearance (10)	Color (5)	Varietal aroma &bouquet (30)	Flavor (15)	Acidity (10)	Defect (10)	General quality (20)	Total (100)
B.2	167	5.87 ns	3.47 ns	19.60 ns	8.20 ns	5.47 ns	5.07 ns	10.93 ns	58.60 ns
	169	5.60	3.13	18.00	8.00	4.93	5.20	10.40	55.27
	170	5.87	3.67	18.00	7.20	5.07	5.20	9.87	54.87
	CV (%)	19.05	20.05	25.44	26.94	30.57	31.04	25.32	16.32
B.3	174	4.75 b	2.44 b	13.13 b	7.13 ns	4.88 ns	4.38 ns	9.50 ns	46.19 ns
	178	6.13 a	3.50 a	16.88 a	7.13	4.00	5.25	10.50	53.38
	179	6.75 a	3.38 a	16.13 a	6.56	4.00	4.75	9.50	51.06
	180	6.50 a	3.63 a	17.63 a	6.38	3.63	4.88	10.25	52.88
	CV (%)	26.49	18.52	25.60	27.87	33.96	28.97	26.12	16.58
B.4	166	6.94 a	3.65 ns	14.82 ns	3.53 b	1.77 b	3.18 b	5.18 b	39.06 b
	168	5.59 b	3.59	17.65	7.24 a	4.94 a	4.71 a	9.88 a	53.59 a
	CV (%)	29.56	14.59	30.80	38.18	33.47	46.56	30.39	21.05
D.1	73	6.82 a	3.65 a	20.12 ns	9.00 a	6.24 a	6.12 a	11.29	63.24 a
	75	5.18 b	2.47 b	16.59	6.88 b	4.82 b	4.82 b	9.41	50.18 b
	CV (%)	19.07	14.69	30.63	33.75	28.25	27.33	32.22	19.08
D.2	69	8.75 a	4.31 a	19.13 ns	8.81 a	6.25 a	6.25 a	12.00 a	65.50 a
	81	4.75 b	2.50 b	16.50	6.56 b	4.63 b	4.63 b	9.00 b	48.56 b
	CV (%)	24.19	24.20	27.45	35.61	33.18	31.80	37.46	23.13
D.3	43	7.38 a	2.94 a	18.38 a	7.88 a	5.63 b	5.00 a	10.50 ns	57.69 a
	44	3.25 c	1.94 c	14.25 b	6.19 b	4.63 b	3.50 b	8.75	42.50 b
	45	5.13 b	2.38 b	18.32 a	9.38 a	6.38 a	5.13 a	11.00	57.75 a
	CV (%)	24.63	24.59	28.06	29.41	27.26	38.40	27.00	15.31
D.5	76	6.00 b	3.06 b	18.38 ns	8.44 ns	5.13 b	5.63 b	10.25 b	56.88 b
	77	9.50 a	4.13 a	20.25	9.94	6.75 a	7.25 a	13.50 a	71.31 a
	78	4.50 c	2.81 b	18.38	8.63	5.50 b	5.00 b	10.75 b	55.56 b
	51	6.25 b	3.19 b	19.88	8.63	6.13 ab	6.00 b	11.50	61.56 b
	CV (%)	29.04	21.17	20.79	25.56	23.99	26.16	22.82	16.20
E.1	55	8.31 a	4.31 a	23.08 a	10.62 a	7.23 a	6.77 a	14.15 a	74.46 a
	56	4.57 b	3.00 b	14.14 b	6.21 b	5.29 b	4.14 b	8.57 b	45.93 c
	57	8.14 a	3.07 b	18.00 ab	9.21 a	6.43 ab	5.86 a	12.00 a	62.71 b
	CV (%)	25.73	21.63	38.64	35.88	24.17	35.19	26.40	22.26
E.2	64	6.75 a	3.13 b	18.38 a	8.81 a	6.00 a	5.75	11.75 a	60.56 a
	65	5.00 b	2.81 b	12.00 b	7.13 ab	4.50 b	4.88	8.50 b	44.81 b
	66	7.13 a	3.63 a	18.38 a	8.81 a	6.38 a	5.75	11.50 a	61.56 a
	74	5.25 b	2.81 b	17.63 a	6.56 b	4.50 b	4.75	9.25 b	50.75 b
	CV (%)	21.67	17.96	29.30	29.17	29.79	32.53	27.36	18.10

Means within the same column with different common letters differ significantly by DMRT; * = $p<0.05$; ns = non-significant

4.4.2 Sensory evaluation in round 2

When the selected treatment combinations in each subgroup that received the highest total wine appreciation scores from sensory tasting in round 1 from subgroup A.1 to E.2 were identified, these selected combinations were selected in round 2 to select the most optimal treatment combination in each group from A to E (table 4.7). The results were as follows:

Group A had a selected combination of 39 (total wine appreciation scores of 71.20).

Group B had a selected combination of 178 (65.87).

Group C had a selected combination with non-significance of 163 (58.88).

Group D had a selected combination of 69 (61.93).

Group E had a selected combination with non-significance of 66 (57.53).

Table 4.7 Wine appreciation chart of Krachai-Dam honey wines by sensory evaluation of 15-23 panelists (round 2).

Group	Treatment	Wine appreciation scores							
		Appearance (10)	Color (5)	Varietal aroma &bouquet (30)	Flavor (15)	Acidity (10)	Defect (10)	General quality (20)	Total (100)
A	60	6.53 bc	3.40 ns	20.40 ab	10.20 a	6.27 a	6.80 ab	12.27 a	65.87 ab
	61	7.33 ab	3.93	22.80 a	10.00 a	6.67 a	6.27 ab	12.00 a	69.00 a
	71	6.67 bc	3.60	18.40 b	8.40 a	6.53 a	5.60 b	10.93 a	60.13 b
	173	6.27 c	3.53	10.00 c	5.40 b	3.60 b	2.93 c	7.20 b	38.93 c
	39	7.73 a	3.87	24.00 a	9.60 a	6.80 a	6.93 a	12.27 a	71.20 a
	CV (%)	15.12	20.12	26.55	29.72	28.95	29.38	26.49	17.80
B	167	5.33 b	3.40 ab	12.40 b	4.80 b	2.67 b	3.47 b	7.73 b	39.80 b
	168	7.07 a	3.73 a	10.80 b	5.40 b	3.47 b	3.87 b	8.53 b	42.87 b
	171	5.20 b	3.07 b	13.20 b	5.40 b	3.07 b	4.40 b	7.73 b	42.07 b
	178	5.20 b	3.87 a	20.80 a	10.40 a	7.07 a	6.27 a	12.27 a	65.87 a
	CV (%)	26.73	21.90	38.59	37.21	46.62	51.78	34.23	28.09
C	163	5.88 b	3.81 ns	19.50 ns	8.06 ns	5.63 ns	5.25 ns	10.75 ns	58.88 ns
	164	6.88 a	3.81	17.63	7.88	5.50	5.13	10.50	57.31
	165	6.88 a	3.75	18.38	7.13	5.38	5.00	10.50	57.00
	CV (%)	16.41	19.66	26.40	28.89	24.13	31.20	26.99	17.53
D	69	7.33 a	3.80 a	16.80 a	9.60 a	6.00 ab	6.13 a	12.27 a	61.93 a
	73	2.93 b	1.20 d	17.20 a	7.80 bc	5.47 b	4.80 ab	9.33 b	48.73 b
	77	6.80 a	2.87 b	16.80 a	9.20 ab	6.67 a	5.60 a	11.73 a	59.67 a
	79	6.53 a	3.67 a	18.00 a	9.40 ab	5.87 ab	4.93 ab	10.93 ab	59.33 a
	45	3.60 b	2.33 c	11.20 b	6.80 c	5.07 b	4.00 b	9.07 b	42.07 b
	CV (%)	30.32	21.39	40.96	25.74	22.20	36.10	26.51	20.38
E	55	5.87 b	2.67 ns	18.40 a	8.20 ns	5.47 b	6.00 ns	10.40 ns	57.00 ns
	66	7.33 a	2.40	13.20 b	9.40	6.93 a	6.27	12.00	57.53
	CV (%)	18.94	22.32	41.68	25.45	25.09	25.96	29.88	21.64

#Means within the same column with different common letters differ significantly by DMRT; * = $p<0.05$; ns= non-significant

4.4.3 Sensory evaluation in round 3.

On the basis of treatment combinations in each group that received the highest total wine appreciation scores from sensory testing in round 2 (from group A, B, D and E), treatment combinations were selected for round 3 to select the combination that would receive the highest wine appreciation scores (Table 4.8). It was found that there were significant differences ($p \leq 0.05$) among the 5 treatment combinations in this round in all wine appreciation parameters. The latter were appearance, color, varietal aroma and bouquet, flavor, acidity, defects, general quality and total wine appreciation. The combination which rendered the highest appreciation scores approved to be combination number 39 (10% w/w of rhizomes in must, 'Rom-Klao' cultivar which gave a dark internal color of rhizomes, Longan honey, Fermivin PDM yeast strain) that had a non-significant difference with combination number 163 (12.5% w/w of rhizomes in must, 'Rom-Klao' cultivar, Longan honey and Lalvin V1116 yeast strain) but gave higher scores than combination number 69 (7.5% w/w of rhizomes in must, 'Nam-Juang' cultivar which gave a purple internal color of rhizomes, Sab-Suea honey and Lalvin V1116 yeast strain), and combination number 178 (15% w/w of rhizomes in must, 'Kheg-Noi#2' cultivar which gave a pale purple internal color of rhizomes, Longan honey and Lalvin V1116 yeast strain), respectively. Therefore, treatment combination that rendered the highest appreciation score was combination number 39, which scored higher than combination number 163, 69 and 178 respectively.

Table 4.8 Wine appreciation chart of Krachai-Dam honey wines by sensory evaluation of 15-23 panelists (round 3).

Treatment	Wine appreciation scores							
	Appearance (10)	Color (5)	Varietal aroma &bouquet (30)	Flavor (15)	Acidity (10)	Defect (10)	General quality (20)	Total (100)
163	6.53 bc	3.65 b	21.71 a	8.38 a	5.41 ab	5.59 ab	10.47 ab	61.74 a
66	5.47 cd	2.00 c	11.12 c	5.82 b	4.47 b	4.18 b	8.00 b	41.06 c
69	5.12 d	2.53 c	16.94 b	7.85 a	5.12 ab	4.18 b	9.35 b	51.09 b
178	7.00 ab	3.41 b	16.06 b	5.56 b	3.18 c	4.29 b	8.35 b	47.85 bc
39	8.06 a	4.35 a	21.35 a	9.44 a	5.88 a	6.29 a	12.24 a	67.62 a
CV (%)	24.20	28.46	33.69	32.65	37.42	39.68	34.54	23.75

Means within the same column with different common letters differ significantly by DMRT; * = $p<0.05$; ns=non-significant

4.5. Selection of the most optimal Krachai-Dam honey wine processing

The main criteria to select the most optimal Krachai-Dam honey wine processing were chemical qualities (TP and AOI) and wine appreciation from sensory testing. When we considered the chemical and pharmaceutical parameters, the treatment combination number 163 gave the highest TP (342 mg GAE/ 100 ml) and AOI (3.42), whereas combination number 39 gave a much lower TP (211.79 mg GAE/ 100 ml) and AOI (2.82). However, when we considered the wine appreciation scores based on sensory testing, combination number 39 gave the highest total appreciation score (67.62), whereas combination number 163 had non-significantly lower on the total score with but had a lower significance on the wine appearance and color appreciation scores than the combination number 39. The final selection must be determined by chemical, pharmaceutical qualities and wine appreciation of trained panelists. Therefore, the most optimal Krachai-Dam honey wine processing was treatment combination number 163 that was produced from 12.5% w/w of rhizomes in must, 'Rom-Klao' cultivar, Longan honey and Lalvin V1116 yeast strain.

Part II: Study on the effects of certain factors on the qualities of Krachai-Dam rhizomes used as raw materials for Krachai-Dam honey wine production.

4.6 Effects of plantation areas and harvesting months of raw materials on wine qualities.

Physical and chemical qualities of wines by each factor are shown in Table 4.9. As for plantation areas (factor 1), There were significant differences in 4 parameters studied, which were L* and b*, TP and AOI. TP and AOI of wines increased as the elevation level of plantation area was higher, whereas L* and b* decreased. As for harvesting months (factor 2), there were significant differences in 5 parameters studied, which were a*, TSS, alcohol percentage, TP and AOI. The wines produced from raw materials which were harvested at January (8 months after growing) gave the highest AOI, TP and a*, but gave the lowest alcohol percentage and TSS, whereas wines from raw materials which was harvested in November, December and March rendered the lowest AOI, TP and a*.

Table 4.9 Effects of plantation areas and harvesting months on wine qualities

Factors	Physical and chemical qualities of wines								
	Wine color			Total soluble solid (°Brix)	Alcohol (% v/v)	pH	Total titrable acidity[1](g/l)	Total phenolic compounds[2]	Anti-oxidant index[3]
	L*	a*	b*						
Areas (factor 1)									
Nakhonphanom	14.74 a	27.71 ns	0.33 a	6.35 ns	11.54 ns	3.61 ns	3.62 ns	287.72 d	1.23 d
Phrae	13.16 ab	26.78	-3.46 b	6.09	11.49	3.69	3.53	305.38 c	1.26 c
Phurua	11.09 b	25.91	-4.36 b	6.35	11.41	3.69	3.69	316.35 b	1.30 b
Maechonluang	10.95 b	25.52	-3.98 b	6.37	11.34	3.53	3.64	353.04 a	1.37 a
Harvesting months (factor 2)									
November	11.32 ns	24.02 b	-3.41 ns	6.16 bc	11.53 a	3.68 ns	3.65 ns	284.83 c	1.25 c
December	11.91	22.30 b	-1.54	5.94 c	11.43 a	3.58	3.66	307.15 b	1.25 c
January	13.70	29.25 a	-4.71	5.99 c	11.09 b	3.64	3.64	337.56 a	1.37 a
February	13.07	31.16 a	-3.62	6.47 b	11.55 a	3.63	3.58	338.85 a	1.33 b
March	12.43	25.66 b	-1.05	6.89 a	11.63 a	3.62	3.57	309.73 b	1.26 c

#Means within the same column with different common letters differ significantly by DMRT; * = $p<0.05$; ns= non-significant
[1] Total titrable acidity shown in the form of citric acid (g/l)
[2] Total phenolic compounds shown in the form of Gallic acid equivalent (mg/100 ml of wines)
[3] Antioxidant index must be ≥1; if <1 shown then there is no antioxidative activity.

When considered 2-factor combination was considered (Table 4.10), there were significant relations between the 2 factors studied on 4 parameters, which were TP, AOI, alcohol percentage and b* (254.50-389.50 mg/100 ml, 1.15-1.44, 10.70-11.87%, -8.98-4.05 respectively).

Table 4.10: Effects of factor combinations in experiment 2.1 on Krachai-Dam honey wine qualities

Factor combinations			Physical and chemical qualities of wines								
Areas	Harvesting months	Tr. No.	Wine color			Total soluble solid (°Brix)	Alcohol (% v/v)	pH	Total titrable acidity[1](g/l)	Total phenolic compounds[2]	Anti-oxidant index[3]
			L*	a*	b*						
Nakhon-phanom	November	TR.2-17	13.44 ns	28.01 ns	3.72 ab	6.47 ns	11.63 abc	3.50 ns	3.63 ns	264.08 h	1.20 fg
	December	TR.2-21	12.69	26.57	-3.29 cdefgh	5.97	11.53 abc	3.57	3.77	296.17 fg	1.17 g
	January	TR.2-1	16.91	26.83	1.17 abcd	6.03	11.17 abcd	3.77	3.77	310.08 def	1.33 bcd
	February	TR.2-25	17.62	29.06	-1.47 abcdef	6.17	11.60 abc	3.43	3.43	296.58 fg	1.22 efg
	March	TR.2-29	13.04	28.06	1.50 abc	7.13	11.77 ab	3.77	3.50	271.67 h	1.23 efg
Phrae	November	TR.2-18	14.80	22.93	-1.96 abcdefg	5.93	11.37 abcd	3.87	3.57	254.50 h	1.15 g
	December	TR.2-22	15.53	24.41	-2.75 cdefgh	5.60	11.63 abc	3.53	3.53	277.33 gh	1.23 efg
	January	TR.2-2	15.42	27.76	-4.60 cdefgh	5.97	11.20 abcd	3.60	3.33	325.98 cd	1.30 cde
	February	TR.2-26	9.96	32.01	-7.72 fgh	6.27	11.40 abc	3.77	3.60	370.00 ab	1.36 bc
	March	TR.2-30	10.08	26.77	-0.26 abcde	6.67	11.87 a	3.67	3.63	299.08 efg	1.27 def
Phurua	November	TR.2-19	7.00	23.13	-8.36 gh	6.17	11.77 ab	3.77	3.80	323.67 cde	1.30 cde
	December	TR.2-23	7.56	19.45	-4.17 cdefgh	5.93	10.70 d	3.37	3.57	318.67 cdef	1.28 def
	January	TR.2-3	12.67	29.68	-6.43 efgh	6.13	11.00 cd	3.60	3.77	324.67 cd	1.40 ab
	February	TR.2-27	14.34	32.66	0.18 abcde	6.67	11.80 a	3.80	3.70	308.83 def	1.30 cde
	March	TR.2-31	13.91	24.63	-3.00 cdefgh	6.83	11.80 a	3.70	3.60	305.92 def	1.21 fg
Maechon luang	November	TR.2-20	10.04	21.99	-7.04 fgh	6.07	11.37 abcd	3.57	3.60	297.06 fg	1.33 bcd
	December	TR.2-24	11.88	18.78	4.05 a	6.27	11.87 a	3.63	3.77	336.42 c	1.32 cd
	January	TR.2-4	9.80	32.74	-8.98 h	5.83	11.00 cd	3.60	3.70	389.50 a	1.44 a
	February	TR.2-28	10.35	30.93	-5.47 defgh	6.77	11.40 abc	3.53	3.60	380.00 ab	1.44 a
	March	TR.2-32	12.70	23.19	-2.45 abcdefgh	6.93	11.07 bcd	3.33	3.53	362.25 b	1.32 cd
CV %			36.82	19.54	118.35	6.59	3.11	5.18	4.74	34.50	3.26

#Means within the same column with different common letters differ significantly by DMRT; * = $p<0.05$; ns= non-significant
[1] Total titrable acidity shown in the form of citric acid (g/l)
[2] Total phenolic compounds shown in the form of Gallic acid equivalent (mg/100 ml of wines)
[3] Antioxidant index must be ≥1; if <1 shown then there is no antioxidative activity.

The most important qualities (TP and AOI) of wines were considered. It was found that the treatment combination of Maechonluang area and a harvesting month in January gave the highest of AOI and TP (1.44 and 389.50 mg/100 ml respectively), whereas the combination of Phrae area and harvesting month in November gave the lowest (1.15 and 254.50 mg/ 100 ml respectively).

4.7 Effects of plantation areas and planting months of raw materials on wine qualities.

Physical and chemical qualities of wines by each factor are shown in Table 4.11. As for plantation areas (factor 1), there were significant differences in 4 parameters studied, which were TP, AOI, pH and b*. TP and AOI of wines increased as elevation level of plantation area was higher, whereas the b* decreased. As for planting months (factor 2), there were significant differences in 4 parameters studied, which were TP, TSS, pH and b*. The wines produced from raw materials which were grown in May gave the highest TP and TA, whereas wines from raw materials which were grown in July gave the highest pH and b*.

Table 4.11 Effects of plantation areas and planting months of raw materials on wine qualities.

Factors	Physical and chemical qualities of wines								
	Wine color			Total soluble solid (°Brix)	Alcohol (% v/v)	pH	Total titrable acidity[1](g/l)	Total phenolic compounds[2]	Anti-oxidant index[3]
	L*	a*	b*						
Areas (factor 1)									
Nakhonphanom	16.84 a	26.85 ns	1.07 a	5.80 ns	11.02 ns	3.93 a	3.52 ns	305.36 c	1.30 c
Phrae	13.44 b	28.55	-3.34 b	6.03	11.19	3.70 c	3.42	319.16 b	1.23 d
Phurua	13.22 b	30.72	-5.31 bc	6.10	11.00	3.81 b	3.53	325.83 b	1.41 b
Maechonluang	11.87 b	30.38	-7.13 c	5.91	10.73	3.89 ab	3.67	351.33 a	1.53 a
Planting months(factor 2)									
May	13.70 ab	30.38 ns	-4.71 b	5.99 ns	11.09 ns	3.64 c	3.64 a	337.56 a	1.37 ab
June	12.79 b	30.06	-4.64 b	5.86	10.86	3.82 b	3.56 ab	330.54 a	1.41 a
July	15.04 a	26.93	-1.69 a	6.03	11.01	4.04 a	3.41 b	308.17 b	1.32 b

Means within the same column with different common letters differ significantly by DMRT; * = $p<0.05$; ns= non-significant
[1] Total titrable acidity shown in the form of citric acid (g/l)
[2] Total phenolic compounds shown in the form of Gallic acid equivalent (mg/100 ml of wines)
[3] Antioxidant index must be ≥1; if <1 shown then there is no antioxidative activity.

When 2-factor combination was considered (Table 4.12), there were significant relations among the 2 factors studied on 4 parameters, which were TP (293.50-389.50 mg/100 ml), pH (3.60-4.20), TP (293.50-389.50 mg/100 ml) and AOI (1.08-1.58).

Table 4.12: Effects of factor combinations in experiment 2.2 on Krachai-Dam wine qualities

Factor combinations			Physical and chemical qualities of wines								
Areas	Planting months	Tr. No.	Wine color			Total soluble solid (°Brix)	Alcohol (% v/v)	pH	Total titrable acidity[1](g/l)	Total phenolic compounds[2]	Anti-oxidant index[3]
			L*	a*	b*						
Nakhon-phanom	May	TR.2-1	16.91 ns	26.83 ns	1.17 ns	6.03 ns	11.17 ns	3.77 bcd	3.77 ns	310.08 bcde	1.33 cde
	June	TR.2-5	17.11	30.44	-3.53	5.53	11.13	3.83 bc	3.47	305.83 cde	1.33 cde
	July	TR.2-9	16.49	23.28	5.56	5.83	10.77	4.20 a	3.33	300.17 de	1.26 e
Phrae	May	TR.2-2	15.42	27.76	-4.60	5.97	11.20	3.60 d	3.33	325.98 bc	1.30 de
	June	TR.2-6	10.59	31.69	-1.68	6.00	10.83	3.80 bc	3.53	322.58 bcd	1.30 de
	July	TR.2-10	14.32	26.18	-3.74	6.13	11.53	3.70 cd	3.40	308.92 bcde	1.08 f
Phurua	May	TR.2-3	12.67	34.20	-6.43	6.13	11.00	3.60 d	3.77	324.67 bc	1.40 cd
	June	TR.2-7	13.58	28.28	-6.91	6.17	10.97	3.73 bcd	3.47	322.75 bcd	1.44 bc
	July	TR.2-11	13.42	29.68	-2.59	6.00	11.03	4.10 a	3.37	330.08 b	1.40 cd
Maechon luang	May	TR.2-4	9.80	32.74	-8.98	5.83	11.00	3.60 d	3.70	389.50 a	1.44 bc
	June	TR.2-8	9.87	29.83	-6.42	5.73	10.50	3.90 b	3.77	371.00 a	1.58 a
	July	TR.2-12	15.94	28.58	-6.00	6.17	10.70	4.17 a	3.53	293.50 e	1.55 ab
	CV %		18.15	14.56	83.86	7.48	3.09	2.65	6.17	3.78	4.73

Means within the same column with different common letters differ significantly by DMRT; * = $p<0.05$; ns= non-significant
[1] Total titrable acidity shown in the form of citric acid (g/l)
[2] Total phenolic compounds shown in the form of Gallic acid equivalent (mg/100 ml of wines)
[3] Antioxidant index must be ≥1; if <1 shown then there is no antioxidative activity.

The most important qualities (TP and AOI) of wines were considered. It was found that the treatment combination of Maechonluang area with a planting month in

May rendered the highest of TP (389.50 mg/100 ml) but the combination in June gave the highest of AOI (1.58), whereas the combination of Maechonluang area and planting month in July gave the lowest of TP (293.50 mg/100 ml), and the combination of Phrae area and planting month at July gave the lowest of AOI (1.08).

4.8 Effects of plantation areas and number of year crops of raw materials on wine qualities

Physical and chemical qualities of wines in each factor are shown in Table 4.13. As for plantation areas (factor 1), there were significant differences in 5 parameters studied which were TP, AOI, pH, L* and b*. TP and AOI of wines increased as the elevation level of plantation area was higher, whereas L* and b* decreased. As for year crop numbers (factor 2), there were significant differences in 3 parameters studied, which were AOI, pH and b*. The wines produced from raw materials which were grown in 1-year crop rendered higher AOI than the ones grown in 2- year crops but gave the lower pH and b*.

Table 4.13 Effects of plantation areas and number of year crops of raw material on wine qualities.

Factors	Physical and chemical qualities of wines								
	Wine color			Total soluble solids (°Brix)	Alcohol (% v/v)	pH	Total titrable acidity[1](g/l)	Total phenolic compounds[2]	Anti-oxidant index[3]
	L*	a*	b*						
Areas (factor 1)									
Nakhonphanom	15.89 a	28.69 ns	1.89 a	6.22 ns	11.13 ns	3.87 a	3.57 ns	308.71 b	1.27 b
Phrae	15.29 ab	27.47	-1.11 b	6.18	11.18	3.82 a	3.48	304.08 b	1.26 b
Phurua	13.87 b	30.22	-6.06 c	5.87	10.93	3.60 b	3.78	319.83 b	1.32 ab
Maechonluang	12.04 c	30.91	-3.51 bc	6.12	10.67	3.78 a	3.62	393.08 a	1.35 a
Year crops (factor 2)									
1-year crop	13.70 ns	29.25 ns	-4.71 b	5.99 ns	11.09 ns	3.64 b	3.64 ns	337.56 ns	1.37 ns
2-year crop	14.85	29.39	0.31 a	6.20	10.87	3.89 a	3.58	325.29	1.23

Means within the same column with different common letters differ significantly by DMRT; * = $p<0.05$; ns=non-significant
[1] Total titrable acidity shown in the form of citric acid (g/l)
[2] Total phenolic compounds shown in the form of Gallic acid equivalent (mg/100 ml of wines)
[3] Antioxidant index must be ≥1; if <1 shown then there is no antioxidative activity.

When 2-factor combination was considered (Table 4.14), there were significant relations between the factors studied on 3 parameters, which were pH, L* and b* (3.60-4.03, 9.80-16.91 and -8.98-2.62 respectively).

The most important qualities (TP and AOI) of wines were considered. It was found that there were no significant differences between these values, but there was a trend thereby the treatment combination of Maechonluang area, grown in 1-year crop, would give the highest of AOI (1.44), whereas the combination of Nakornpanom area, grown in 2-year crop gave the lowest one (1.21). Moreover, the combination of Maechonluang area, grown in 2-year crops, gave the highest of TP (396.67 mg/100 ml), whereas the combination of Nakornpanom area, grown in 2-year crop, gave the lowest one (307.33 mg/ 100 ml).

Table 4.14 Effects of factors combinations in experiment 2.3 on Krachai-Dam honey wine qualities.

Factor combinations			Physical and chemical qualities of wines								
Areas	Year crops	Tr. No.	Wine color			Total soluble solid (°Brix)	Alcohol (% v/v)	pH	Total titrable acidity[1](g/l)	Total phenolic compounds[2]	Anti-oxidant index[3]
			L*	a*	b*						
Nakhon-phanom	1-year crop	TR.2-1	16.91 ns	26.83 ns	1.17 ns	6.03 ns	11.17 ns	3.77 bc	3.77 ns	310.08 ns	1.33 ns
	2-year crop	TR.2-33	14.86	30.55	2.62	6.40	11.10	3.97 ab	3.37	307.33	1.21
Phrae	1-year crop	TR.2-2	15.42	27.76	-4.60	5.97	11.20	3.60 c	3.33	325.98	1.30
	2-year crop	TR.2-34	15.16	27.17	2.37	6.40	11.17	4.03 a	3.63	282.17	1.22
Phurua	1-year crop	TR.2-3	12.67	29.68	-6.43	6.13	11.00	3.60 c	3.77	324.67	1.40
	2-year crop	TR.2-35	15.07	30.76	-5.69	5.60	10.87	3.60 c	3.80	315.00	1.25
Maechon luang	1-year crop	TR.2-4	9.80	32.74	-8.98	5.83	11.00	3.60 c	3.70	389.50	1.44
	2-year crop	TR.2-36	14.29	29.07	1.96	6.40	10.33	3.97 ab	3.53	396.67	1.26
CV %			10.92	12.53	62.10	5.84	3.33	3.29	5.71	7.87	3.81

Means within the same column with different common letters differ significantly by DMRT; * = $p<0.05$; ns=non-significant
[1] Total titrable acidity shown in the form of citric acid (g/l)
[2] Total phenolic compounds shown in the form of Gallic acid equivalent (mg/100 ml of wines)
[3] Antioxidant index must be ≥1; if <1 shown then there is no antioxidative activity.

4.9 Effects of (a) plantation area, (b) storage period and (c) storage method of raw materials on wine qualities

Physical and chemical qualities of wines by each factor are shown in Table 4.15. As for plantation area (factor 1), there were significant differences in 6 parameters studied, which were TP, AOI, pH, L*, a* and b*. TP, AOI and a* of wines increased as the elevation level of plantation area was higher, whereas L* and b* decreased. As for storage period (factor 2), there were significant differences in all parameters studied. TP, AOI and a* of wines decreased as the storage period was longer, whereas pH, TSS, L* and b* increased. As for storage method (factor 3), there were significant differences in all parameters except the TA and b*. The cold storage method gave the highest TP, AOI and a*, but rendered the lowest pH, TSS, alcohol percentage and L*. Layout on the ground and keeping in net bags gave similar results, in all parameters.

Table 4.15 Effects of plantation areas, storage periods, and storage methods of raw material on wine qualities.

Factors	Physical and chemical qualities of wines								
	Wine color			Total soluble solid (°Brix)	Alcohol (% v/v)	pH	Total titrable acidity[1](g/l)	Total phenolic compounds[2]	Anti-oxidant index[3]
	L*	a*	b*						
Areas (factor 1)									
Nakhonphanom	19.86 a	24.27 b	1.00 a	6.43 ns	11.24 ns	3.92 a	3.55 ns	277.33 c	1.24 c
Phrae	18.06 b	26.70 a	-1.32 b	6.43	11.36	3.83 b	3.50	299.28 b	1.24 c
Phurua	14.84 c	26.65 a	-2.07 b	6.40	11.38	3.92 a	3.55	293.02 b	1.31 b
Maechonluang	13.71 d	28.56 a	-2.93 c	6.41	11.27	3.87 ab	3.61	350.11 a	1.37 a
Storage periods (factor 2)									
0 month	13.70 c	29.25 a	-4.71 c	5.99 b	11.09 c	3.64 c	3.64 a	337.56 a	1.37 a
3 month	17.47 b	25.52 b	-0.52 b	6.67 a	11.56 a	3.94 b	3.58 a	296.71 b	1.30 b
6 month	18.69 a	24.87 b	1.24 a	6.59 a	11.29 b	4.08 a	3.44 b	280.54 c	1.22 c
Storage methods (factor 3)									
Layout	17.24 a	25.49 b	-0.91 ns	6.41 ab	11.32 ab	3.98 a	3.57 ns	286.55 c	1.27 b
Net bag	17.02 a	25.57 b	-1.32	6.59 a	11.42 a	3.86 b	3.49	301.27 b	1.28 b
Cold storage	15.59 b	28.57 a	-1.76	6.25 b	11.21 b	3.82 b	3.60	326.99 a	1.33 a

Means within the same column with different common letters differ significantly by DMRT; * = $p<0.05$; ns=non-significant
[1] Total titrable acidity shown in the form of citric acid (g/l)
[2] Total phenolic compounds shown in the form of Gallic acid equivalent (mg/100 ml of wines)
[3] Antioxidant index must be ≥1; if <1 shown then there is no antioxidative activity.

Each pair of factor combinations was considered (Table 4.16). The effects of 2-factor combinations and 3 factors, which were plantation area (factor 1), storage period (factor 2) and storage methods (factor 3) of raw materials on wine qualities, were studied. There were significant relation between the 2 factors combination of plantation area (factor

1) and storage period (factor 2) in 6 parameters of wine qualities, which were pH, TA, TSS, L*, a* and b*. As for wine color, the combination of Nakhonphanom area and storage period of 6 months after harvest gave the highest L* and 6* (22.95 and 2.34 respectively) and the lowest a* (21.21), whereas the combination Maechonluang area and storage period of 0 months after harvest gave the highest a* (32.74) and the lowest L* and b* (9.80 and – 8.98 respectively). As for pH, the combinations of Nakhonphanom, Phurua and Maechonluang area, with a storage period of 3 and 6 months after harvest; and Phrae area with a storage period of 6 months, gave higher (3.97-4.17) than other combinations (3.60-3.78). As for TSS, the combinations of Nakhonphanom area and a storage period of 0 month after harvest, and Phurua area with a storage period of 0 month, gave the highest (3.77 g/l). The combination of Nakhonphanom area and 6 months after harvest, gave the lowest (3.28 g/l). As for TP, the combination of Maechonluang area and a storage period of 0 month after harvest, gave the highest (389.50 mg/ 100 ml), whereas the combination of Nakhonphanom area with a storage period of 6 months, gave the lowest one (240.28 mg/ 100 ml).

The effects of 2 factors combinations of plantation area (factor 1) and storage method (factor 3) of raw materials on wine qualities showed that there were significant relations between the 2 factors in 3 parameters studied, which were alcohol percentage, pH and TP. As for alcohol percentage, the combination of Nakhonphanom area and keeping in net bags gave the highest (11.58%), whereas the combination of Maechonluang area and cold storage gave the lowest one (10.87). As for pH, the combination of Nakhonphanom area and layout on the ground gave the highest (4.09), whereas the combinations of Nakhonphanom area and cold storage and Phrae area and keeping in net bags gave the lowest ones (3.74 and 3.79 respectively). As for TP, the combination of Maechonluang area and cold storage gave the highest (380.60 mg/ 100 ml), whereas the combinations of Nakhonphanom area and layout on the ground and keeping in net bags, and Phurua area and layout on the ground gave the lowest ones (296.91, 271.24 and 268.49 mg/ 100 ml respectively)

It was found that the effects of 2 factors combinations between storage period (factor 2) and storage method (factor 3) of raw materials on wine qualities had significant relations between the 2 factors in 6 parameters studied, which were pH, TA, TP, AOI, L* and b*. As for pH, the combination of storage period of 6 months after harvest and layout on the ground gave the highest one (4.23), whereas the combinations between storage period of 0 month after harvest and all storage methods gave the lowest one (3.64). As for TA, the combination of storage period of 6 months after harvest and layout on the ground gave the lower (3.18 g/l) than other combinations (3.51-3.64 g/l). As for TP, the combinations of a storage period of 0 month after harvest and all storage methods, and between a storage period of 3 months and cold storage gave the highest ones (337.56 and 328.92 mg/ 100 ml respectively), whereas the combinations of a storage period of 3 and 6 months after harvest and layout on the ground gave the lowest ones (264.51 and 257.59 mg/ 100 ml respectively). As for AOI, the combinations between a storage period of 0 month after harvest and all storage methods gave the highest (1.37), whereas the combinations between a storage period at 6 months after harvest and layout on the ground and keeping in net bags gave the lowest one (1.18, respectively). As for wine color, the combinations of a storage period of 0 month after harvest and all storage methods gave the lowest L* and b* (13.70 and -4.71 respectively), whereas the combinations of a storage period of 6 months after harvest and layout on the ground

and keeping in net bags gave the highest L* (19.74 and 18.82 respectively) and b* (3.61 and 2.03 respectively). Moreover the L* of the combination of a storage period of 3 months after harvest and keeping in net bags and the b* of the combination of storage period of 3 months after harvest and cold storage, were also the highest ones (18.55 and 1.34 respectively).

Table 4.16 Effects of each pair of factor combinations in experiment 2.4 on factors (plantation area, storage methods and storage period) of raw materials on wine qualities.

Areas	Storage periods	Physical and chemical qualities of wines								
		Wine color			Total soluble solid (°Brix)	Alcohol (% v/v)	pH	Total titrable acidity[1](g/l)	Total phenolic compounds[2]	Anti-oxidant index[3]
		L*	a*	b*						
Nakhon-phanom	0 month	16.91 cd	26.83 bcde	1.17 ab	6.03 ns	11.17 ns	3.77 b	3.77 a	310.08 bc	1.33 ns
	3 month	19.73 b	24.78 cdef	-0.52 b	6.73	11.34	3.97 a	3.59 abcd	281.63 de	1.25
	6 month	22.95 a	21.21 f	2.34 a	6.52	11.22	4.03 a	3.28 d	240.28 f	1.16
Phare	0 month	15.42 d	27.76 bcd	-4.60 c	5.97	11.20	3.60 b	3.33 cd	325.98 bc	1.30
	3 month	18.38 bc	28.31 bc	-0.45 b	6.64	11.51	3.78 b	3.54 abcd	300.73 cd	1.26
	6 month	20.38 b	24.03 def	1.09 ab	6.67	11.38	4.10 a	3.61 abc	271.13 e	1.17
Phurua	0 month	12.67 e	29.68 ab	-6.43 c	6.13	11.00	3.60 b	3.77 a	324.67 bc	1.40
	3 month	16.03 d	23.24 ef	-0.64 b	6.46	11.79	4.00 a	3.46 abcd	272.18 e	1.31
	6 month	15.81 d	27.04 bcde	0.87 ab	6.62	11.36	4.17 a	3.43 bcd	282.20 de	1.23
Maechon luang	0 month	9.80 f	32.74 a	-8.98 d	5.83	11.00	3.60 b	3.70 ab	389.50 a	1.44
	3 month	15.73 d	25.75 bcde	-0.48 b	6.86	11.58	4.01 a	3.71 ab	332.31 b	1.35
	6 month	15.60 d	27.19 bcde	0.67 ab	6.56	11.22	4.01 a	3.42 bcd	328.53 bc	1.32
Areas	**Storage methods**									
Nachon-phanum	Layout	20.36 ns	24.33 ns	1.37 ns	6.52 ns	11.02 cd	4.09 a	3.68 ns	296.91 e	1.22 ns
	Net bag	19.95	22.77	1.39	6.46	11.58 a	3.93 ab	3.44	271.24 e	1.23
	Cold storage	19.28	25.72	0.22	6.31	11.13 bcd	3.74 b	3.51	290.84 cde	1.28
Phare	Layout	19.17	25.59	-0.56	6.29	11.43 abc	3.88 ab	3.57	282.76 de	1.23
	Net bag	18.15	25.86	-1.20	6.68	11.32 abc	3.79 b	3.34	290.05 cde	1.22
	Cold storage	16.84	28.67	-2.20	6.31	11.33 abc	3.81 ab	3.58	325.03 bc	1.28
Phurua	Layout	14.86	25.33	-1.67	6.29	11.41 abc	3.97 ab	3.52	268.49 e	1.29
	Net bag	14.91	26.40	-2.45	6.77	11.24 abcd	3.98 ab	3.60	299.18 cde	1.30
	Cold storage	14.74	28.24	-2.08	6.16	11.49 ab	3.82 ab	3.53	311.38 bcd	1.35
Maechon luang	Layout	14.58	26.74	-2.77	6.56	11.40 abc	4.00 ab	3.49	325.05 bc	1.34
	Net bag	15.07	27.26	-3.04	6.46	11.53 ab	3.73 b	3.58	344.59 b	1.35
	Cold storage	11.48	31.68	-2.98	6.23	10.87 d	3.89 ab	3.77	380.69 a	1.42
Storage periods	**Storage methods**									
0 month	Layout	13.70 c	29.25 ns	-4.71 c	5.99 ns	11.09 ns	3.64 e	3.64 a	337.56 a	1.37 a
	Net bag	13.70 c	29.25	-4.71 c	5.99	11.09	3.64 e	3.64 a	337.56 a	1.37 a
	Cold storage	13.70 c	29.25	-4.71 c	5.99	11.09	3.64 e	3.64 a	337.56 a	1.37 a
3 month	Layout	18.29 ab	23.59	-1.62 b	6.66	11.53	4.08 bc	3.51 a	264.51 d	1.26 c
	Net bag	18.55 a	24.11	-1.29 b	6.99	11.76	3.80 d	3.66 a	296.71 bc	1.28 c
	Cold storage	15.56 bc	28.86	1.34 a	6.37	11.38	3.94 cd	3.56 a	328.92 a	1.34 ab
6 month	Layout	19.74 a	23.64	3.61 a	6.59	11.33	4.23 a	3.54 a	257.59 d	1.18 d
	Net bag	18.82 a	23.35	2.03 a	6.78	11.41	4.13 ab	3.18 b	269.54 cd	1.18 d
	Cold storage	17.49 ab	27.61	-1.91 b	6.40	11.14	3.87 d	3.59 a	314.48 ab	1.29 bc
CV%		11.57	13.10	119.36	7.26	2.73	3.57	7.79	4.80	4.15

Means within the same column with different common letters differ significantly by DMRT; * = $p<0.05$; ns = non-significant

[1] Total titrable acidity shown in the form of citric acid (g/l)

[2] Total phenolic compounds shown in the form of Gallic acid equivalent (mg/100 ml of wines)

[3] Antioxidant index must be ≥1; if <1 shown then there is no antioxidative activity.

When 3-factor combination was considered (Table 4.17), there were significant relations among the 3 factors studied in qualities of wines: alcohol percentage, pH and TP (10.70-12.13%, 3.60-4.30 and 213.72-389.50 mg/ 100 ml respectively).

Table 4.17 Effects of factors combinations in experiment 2.4 on Krachai-Dam honey wine qualities.

Factor combination				Physical and chemical qualities of wines								
areas	Storage periods	Storage methods	Tr no.	Wine color			Total soluble solid (°Brix)	Alcohol (% v/v)	pH	Total titrable acidity[1](g/l)	Total phenolic compounds[2]	Anti-oxidant index[3]
				L	a*	b*						
Nakhon-phanom	0 month	Layout	TR.2-1	16.91 ns	26.83 ns	1.17 ns	6.03 n	11.17 efghi	3.77 fghi	3.77 ns	310.08 bcdef	1.33 ns
		Net bag	TR.2-1	16.91	26.83	1.17	6.03	11.17 efghi	3.77 fghi	3.77	310.08 bcdef	1.33
		Cold storage	TR.2-1	16.91	26.83	1.17	6.03	11.17 efghi	3.77 fghi	3.77	310.08 bcdef	1.33
	3 months	Layout	TR.2-37	20.08	23.11	-1.90	6.57	10.80 hi	4.30 a	3.72	276.25 ghij	1.22
		Net bag	TR.2-41	20.33	23.96	-1.31	7.00	12.00 ab	3.77 fghi	3.53	274.91 ghij	1.23
		Cold storage	TR.2-45	18.78	27.26	1.65	6.63	11.23 efghi	3.83 efghi	3.53	293.72 defghi	1.30
	6 months	Layout	TR.2-49	24.09	23.04	4.85	6.97	11.10 efghi	4.20 ab	3.57	223.40 lm	1.12
		Net bag	TR.2-53	22.61	17.52	4.32	6.33	11.57 abcdef	4.27 a	3.03	228.73 lm	1.14
		Cold storage	TR.2-57	22.15	23.06	-2.15	6.27	11.00 fghi	3.63 hi	3.23	268.70 hij	1.21
Phrae	0 month	Layout	TR.2-2	15.42	27.76	-4.60	5.97	11.20 efghi	3.60 i	3.33	325.98 bc	1.30
		Net bag	TR.2-2	15.42	27.76	-4.60	5.97	11.20 efghi	3.60 i	3.33	325.98 bc	1.30
		Cold storage	TR.2-2	15.42	27.76	-4.60	5.97	11.20 efghi	3.60 i	3.33	325.98 bc	1.30
	3 months	Layout	TR.2-38	20.28	26.96	-1.42	6.63	11.50 bcdefg	3.80 fghi	3.67	282.17 fghij	1.24
		Net bag	TR.2-42	18.68	25.07	-0.48	7.00	11.37 cdefgh	3.63 hi	3.57	284.83 efghij	1.24
		Cold storage	TR.2-46	16.16	32.91	0.55	6.30	11.67 abcde	3.90 defgh	3.40	335.20 b	1.32
	6 months	Layout	TR.2-50	21.82	22.04	4.33	6.27	11.60 abcdef	4.23 a	3.70	240.13 kl	1.14
		Net bag	TR.2-54	20.36	24.74	1.48	7.07	11.40 bcdefgh	4.13 abcd	3.13	259.35 jk	1.13
		Cold storage	TR.2-58	18.95	25.32	-2.55	6.67	11.13 efghi	3.93 cdefg	4.00	313.92 bcd	1.22
phurua	0 month	Layout	TR.2-3	12.67	29.68	-6.43	6.13	11.00 fghi	3.60 i	3.77	324.67 bc	1.40
		Net bag	TR.2-3	12.67	29.68	-6.43	6.13	11.00 fghi	3.60 i	3.77	324.67 bc	1.40
		Cold storage	TR.2-3	12.67	29.68	-6.43	6.13	11.00 fghi	3.60 i	3.77	324.67 bc	1.40
	3 months	Layout	TR.2-39	15.66	21.03	-1.67	6.43	11.90 abcd	4.03 abcdef	3.23	213.72 m	1.29
		Net bag	TR.2-43	17.10	23.01	-1.71	6.93	11.53 bcdef	4.07 abcde	3.67	295.74 defgh	1.31
		Cold storage	TR.2-47	15.32	25.66	1.46	6.00	11.93 abc	3.90 defgh	3.47	307.09 bcdef	1.34
	6 months	Layout	TR.2-51	16.25	25.26	3.09	6.30	11.33 cdefgh	4.27 a	3.57	267.09 ij	1.17
		Net bag	TR.2-55	14.96	26.49	0.79	7.23	11.20 efghi	4.27 a	3.37	277.13 ghij	1.19
		Cold storage	TR.2-59	16.22	29.37	-1.27	6.33	11.53 bcdef	3.97 bcdefg	3.37	302.39 cdefg	1.32
Maehon luang	0 month	Layout	TR.2-4	9.80	32.74	-8.98	5.83	11.00 fghi	3.60 i	3.70	389.50 a	1.44
		Net bag	TR.2-4	9.80	32.74	-8.98	5.83	11.00 fghi	3.60 i	3.70	389.50 a	1.44
		Cold storage	TR.2-4	9.80	32.74	-8.98	5.83	11.00 fghi	3.60 i	3.70	389.50 a	1.44
	3 months	Layout	TR.2-40	17.12	23.24	-1.50	7.00	11.90 abcd	4.17 abc	3.43	285.92 defghi	1.31
		Net bag	TR.2-44	18.08	24.41	-1.67	7.03	12.13 a	3.73 ghi	3.87	331.33 b	1.34
		Cold storage	TR.2-48	11.99	29.61	1.71	6.53	10.70 i	4.13 abcd	3.83	379.67 a	1.42
	6 months	Layout	TR.2-52	16.82	24.23	2.17	6.83	11.30 defghi	4.23 a	3.33	299.73 cdefg	1.27
		Net bag	TR.2-56	17.34	24.64	1.52	6.50	11.47 bcdefg	3.87 efghi	3.17	312.93 bcde	1.28
		Cold storage	TR.2-60	12.65	32.69	-1.68	6.33	10.90 ghi	3.93 cdefg	3.77	372.92 a	1.40
CV %				11.57	13.10	119.36	7.26	2.73	3.57	7.79	4.80	4.15

Means within the same column with different common letters differ significantly by DMRT; * = $p<0.05$; ns=non-significant

[1] Total titrable acidity shown in the form of citric acid (g/l)

[2] Total phenolic compounds shown in the form of Gallic acid equivalent (mg/100 ml of wines)

[3] Antioxidant index must be ≥1; if <1 shown then there is no antioxidative activity.

As the main purpose of Krachai-Dam honey wines consumption was to produce herbal wine, the most important qualities considered were TP and AOI of wines. The following was found. As for TP, the treatment combination of Maechonluang area, a storage period of 0 month after harvest and all storage methods gave the highest TP (389.50 mg/ 100 ml), which were non significantly higher than the treatment combinations of Maechonluang area, a storage period of 3 and 6 months after harvest and cold storage (379.67 and 372.92 mg/ 100 ml respectively). However, the combination of Phurua area, a storage period of 3 months after harvest and layout on the ground gave the lowest one (213.72 mg/ 100 ml), which was non significantly lower than the combinations of Nakhonphanom area, a storage period of 6 months after harvest and layout on the ground (223.40 mg/ 100 ml) and keeping in net bags (228.73 mg/ 100 ml). As for AOI, there were non-significant differences among the treatment combinations studied. However, the treatment combinations between Maechonluang area, a storage period of 0 month after harvest and all storage methods rendered a trend with have the highest AOI with non-significant (1.44), whereas the combination of Nakhonphanom area, a storage period of 6 months after harvest and layout on the ground, gave a trend with the lowest one (1.12).

4.10 Grouping of the treatment combinations of part II

The selection of high quality Krachai-Dam wine processing considered not only gave the highest TP and AOI, but also received the highest acceptable scores from sensory evaluations of panelists. The limitation of sensory evaluation is that the number of samples should not exceed 5, while our sample had 56. Thus, this study needed to use an UPGMA for grouping these samples by their similarities of 9 quality parameters. Following that the result can be shown in a dendrogram (Figure 4.2). The Krachai-Dam honey wines processes can be classified in 6 main groups as follows:

Group P: this could be sub-classified into 5 subgroups, which were subgroup P.1, consisting of 3 treatment combinations: 2-46, 2-59 and 2-33; subgroup P.2, consisting of 4 combinations: 2-47, 2-56, 2-01 and 2-34; subgroup P.3, consisting of 5 combinations: 2-30, 2-31, 2-29, 2-27 and 2-17; subgroup P.4, consisting of 2 combinations: 2-40 and 2-43; and subgroup P.5, consisting of 5 combinations: 2-38, 2-42, 2-45, 2-41 and 2-44.

Group Q: this could be sub-classified into 2 subgroups, which were subgroup Q.1, consisting of 5 treatment combinations: 2-21, 2-22, 2-18, 2-10 and 2-25; subgroup Q.2, consisting of 1 treatment combination: 2-57.

Group R: this could be sub-classified into 2 subgroups, which were subgroup R.1, consisting of 5 treatment combinations: 2-37, 2-58, 2-52, 2-55 and 2-54; subgroup R.2, consisting of 4 combinations: 2-50, 2-51, 2-49 and 2-09.

Group S: this had 1 subgroup consisting of 2 treatment combination: 2-39 and 2-53.

Group T: this could be sub-classified into 4 subgroups, which were subgroup T.1, consisting of 5 treatment combinations: 2-05, 2-11, 2-12, 2-48 and 2-60; subgroup T.2, consisting of 3 combinations: 2-03, 2-35 and 2-08; subgroup T.3, consisting of 3 combinations: 2-02, 2-07 and 2-06; and subgroup T.4, consisting of 4 combinations: 2-04, 2-26, 2-28 and 2-36.

Group U: this had1 subgroup consisting of 5 treatment combinations: 2-19, 2-20, 2-23, 2-32 and 2-24.

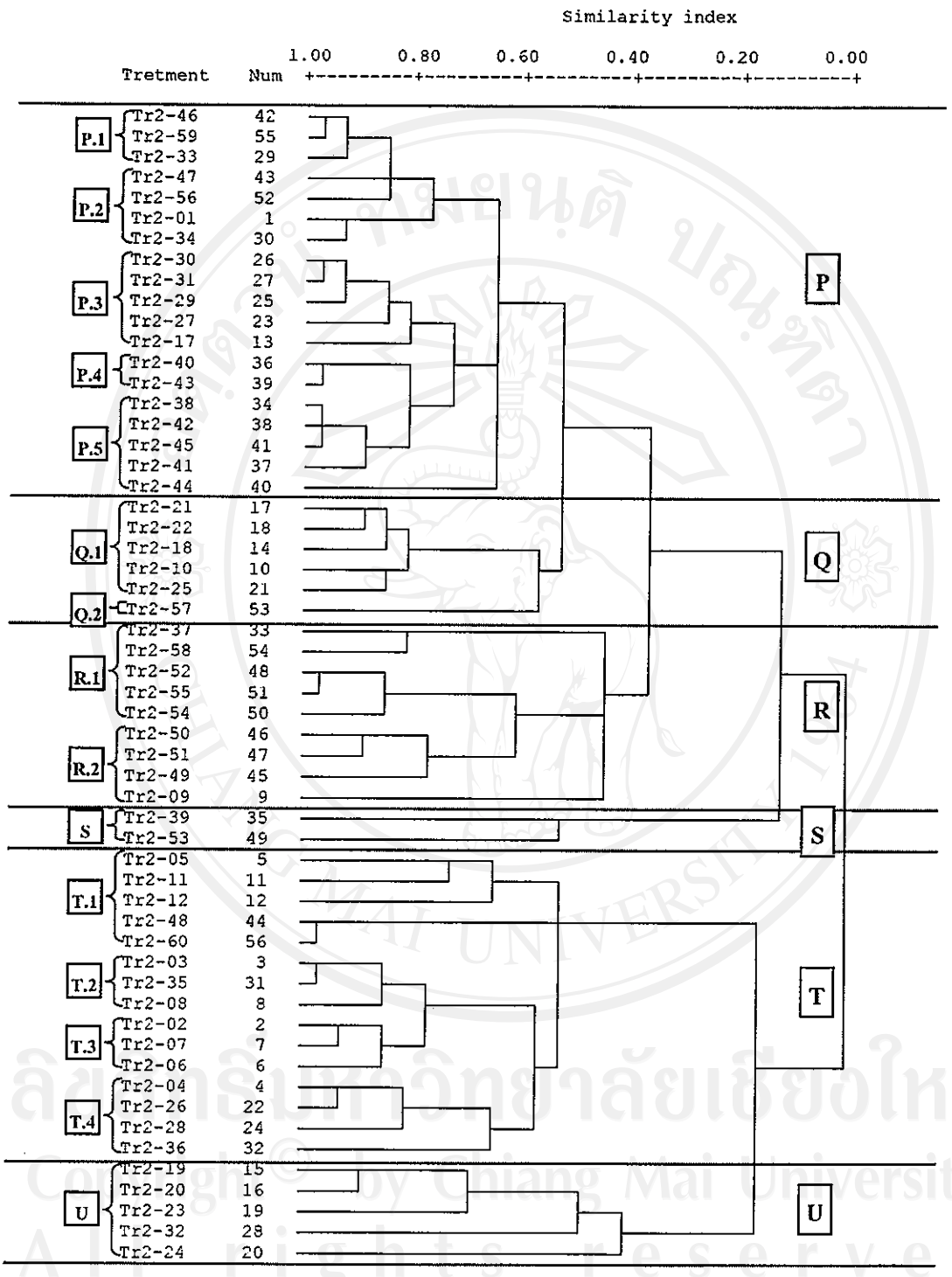

Figure 4.2 Dendrogram obtained from 9 physical and chemical characters of Krachai-Dam honey wine (part II from experiment 2.1 to 2.4) by UPGMA.

4.11 Sensory evaluation

4.11.1 Sensory evaluation in round 1

Sensory testing by at least 15-trained panelists were obtained and analyzed to select the most optimal Krachai-Dam honey wine processing, taking into account the factors affecting raw materials, which would give the highest total appreciation scores of each group (Table 4.18). The results are as follows;

Group P had 5 subgroups. The selected treatment combinations of each subgroup were treatment combination number 2-33 (total appreciation scores of 62.38) in subgroup P.1 with non-significance, combination number 2-56 (65.12) in subgroup P.2, combination number 2-31 (68.41) in subgroup P.3, combination number 2-43 (66.29) in subgroup P.4 with non-significance and combination number 2-44 (60.35) with non-significance.

Group Q had 2 subgroups. The selected treatment combination of subgroup Q.1 was combination number 2-25 (total appreciation scores of 60.00) with non-significance, whereas subgroup Q.2 had only one treatment combination, i.e. number 2-57.

Group R had 2 subgroups. The selected treatment combinations of each subgroup were combination number 2-58 (total wine appreciation scores of 62.05) in subgroup R.1 and combination number 2-9 (58.88) in subgroup R.2 with non-significance.

Group T had 4 subgroups. The selected treatment combinations of each subgroup were combination number 2-48 (total wine appreciation scores of 64.14) in subgroup T.1 with non-significance, number 2-8 (70.22) in subgroup T.2 with non-significance, number 2-7 (68.30) in subgroup T.3 and number 2-28 in subgroup T.4.

Table 4.18 Wine appreciation chart of Krachai-Dam honey wines by sensory evaluation of 15-23 panelists in crop year 2005-2006 (round 1).

Group	Treatment	Wine appreciation score: Appearance (10)	Color (5)	Varietal aroma &bouquet (30)	Flavor (15)	Acidity (10)	Defect (10)	General quality (20)	Total (100)
P.1	2-33	8.50 a	2.31 ns	18.75 ns	8.06 ns	6.00 ns	5.38 ns	12.38 ns	62.38 ns
	2-46	6.75 b	3.50	21.38	8.44	5.63	5.00	11.50	62.19
	2-59	7.25 b	3.75	17.63	6.94	5.50	5.25	11.13	57.44
	CV (%)	19.17	24.59	25.90	26.08	30.97	31.12	25.81	16.48
P.2	2-1	6.94 bc	2.59 c	16.59 b	6.88 b	4.94 ns	4.82 ns	8.94 b	51.71 b
	2-34	7.88 ab	3.24 bc	17.29 b	8.47 ab	5.76	5.53	12.00 a	60.18 a
	2-47	8.00 a	4.00 a	19.76 ab	8.29 ab	5.76	4.94	12.12 a	62.88 a
	2-56	7.71 ab	3.59 ab	21.53 a	9.18 a	6.00	5.88	12.24 a	65.12 a
	CV (%)	19.48	28.90	28.75	26.77	29.28	24.30	25.67	17.03
P.3	2-17	5.41 c	2.12 c	15.88 b	8.12 ns	4.82 ns	4.82 b	10.71 c	51.88 c
	2-27	7.88 a	3.88 a	20.47 a	9.00	5.65	6.12 a	13.06 ab	66.06 a
	2-29	6.71 b	3.00 b	18.35 ab	8.29	5.53	5.88 a	11.29 c	59.06 b
	2-30	7.18 ab	3.24 b	19.06 ab	9.18	5.53	6.12 a	11.76 bc	62.06 ab
	2-31	8.12 a	3.18 a	20.47 a	9.88	5.76	6.12 a	13.88 a	68.41 a
	CV (%)	23.01	18.44	26.40	23.62	26.42	22.54	19.96	14.92
P.4	2-40	6.47 ns	3.65 ns	21.53 ns	7.76 a	5.53 ns	6.00 ns	12.47 ns	63.41 ns
	2-43	6.71	3.41	21.18	9.35 a	6.47	6.24	12.94	66.29
	CV (%)	16.77	11.26	22.72	24.96	33.45	21.44	20.64	15.25
P.5	2-38	6.47 bc	3.53 ab	16.94 ns	7.76 ns	4.47 ns	4.59 ns	10.35 ns	54.12 ns
	2-41	8.35 a	3.18 b	18.71	7.59	5.06	5.18	11.41	59.47
	2-42	7.41 ab	3.24 b	17.65	8.82	5.65	4.71	11.76	59.24
	2-44	5.88 c	4.00 a	18.35	9.53	5.53	5.18	11.88	60.35
	2-45	6.24 c	3.59 ab	16.94	7.94	4.82	4.82	10.82	55.18
	CV (%)	23.03	22.01	32.56	28.65	36.59	31.92	27.68	18.88
Q.1	2-10	7.38 bc	2.88 ns	17.63 ns	8.06 ns	4.88 ns	5.00 ns	10.25 ns	56.06 ns
	2-18	7.75 ab	3.63	18.38	8.25	5.88	5.00	10.88	59.75
	2-21	6.00 d	3.25	15.75	6.94	4.75	4.25	9.38	50.31
	2-22	6.75 cd	3.50	15.75	7.50	4.50	4.75	9.25	52.00
	2-25	8.50 a	3.19	19.13	8.44	5.13	5.25	10.38	60.00
	CV (%)	17.17	29.92	36.59	30.82	36.14	28.02	28.00	22.93

Means within the same column with different common letters differ significantly by DMRT; * = $p<0.05$; ns = non-significant

Table 4.18 (continued)

Group	Treatment	Wine appreciation score							
		Appearance (10)	Color (5)	Varietal aroma &bouquet (30)	Flavor (15)	Acidity (10)	Defect (10)	General quality (20)	Total (100)
R.1	2-37	8.18 a	3.64 ab	16.64 ns	8.18 ns	5.27 ns	5.18 ns	10.73 ns	57.82 ab
	2-52	7.82 ab	4.00 a	19.36	8.32	5.55	4.91	11.55	61.50 a
	2-54	6.18 c	3.23 bc	16.64	7.23	5.27	4.45	10.36	53.36 b
	2-55	7.73 ab	3.86 a	19.64	8.45	5.18	4.91	11.18	60.95 a
	2-58	6.91 bc	2.95 c	20.18	9.00	6.18	5.00	11.82	62.05 a
CV (%)		22.97	22.72	31.58	27.16	29.51	32.31	22.99	17.04
R.2	2-9	8.50 a	3.31 ns	17.63 ns	8.44 ns	5.13 ns	4.75 ns	11.13 ns	58.88 ns
	2-49	4.75 b	3.38	19.13	7.50	5.25	4.63	10.25	54.88
	2-50	7.63 a	3.50	19.13	7.69	5.13	5.00	10.25	58.31
	2-51	7.38 a	3.34	19.88	7.13	5.13	4.63	9.50	56.97
CV (%)		22.78	29.45	24.68	24.59	35.01	39.26	31.56	19.16
T.1	2-5	6.82	2.55 b	16.36	8.45	6.09	5.27	10.91	56.45
	2-11	7.64	4.14 a	20.18	8.32	5.64	5.09	11.55	62.55
	2-12	7.82	2.82 b	18.55	7.77	5.82	5.36	12.00	60.14
	2-48	7.81	3.90 a	19.71	9.00	5.90	5.90	11.90	64.14
	2-60	6.91	3.73 a	19.09	9.00	5.91	4.82	12.09	61.55
CV (%)		21.34	33.11	32.12	26.07	28.42	29.78	26.29	20.21
T.2	2-3	8.00 ns	3.50 ab	21.17 ab	8.17 ns	5.44 ns	5.44 ns	11.33 ns	63.06 ns
	2-8	7.67	3.89 a	23.67 a	9.67	6.00	6.11	13.22	70.22
	2-35	7.89	3.00 b	20.00 b	8.33	5.44	5.78	11.56	62.00
CV (%)		16.96	26.31	19.82	31.20	27.07	28.46	29.66	19.18
Significance		ns	*	*	ns	ns	ns	ns	ns
T.3	2-2	5.20 c	3.15 b	19.50 ns	8.55 ns	5.50 ns	5.80 ns	11.40 ns	59.10 b
	2-6	6.90 b	2.95 b	18.90	9.15	5.50	5.90	12.20	61.50 b
	2-7	8.40 a	4.05 a	21.60	9.45	5.70	5.90	13.20	68.30 a
CV (%)		18.42	21.60	21.64	27.28	25.96	28.16	22.83	16.20
T.4	2-4	6.30 b	3.65 ns	18.30 ns	8.70 ns	5.30 ns	4.70 ns	11.00 b	57.95 b
	2-26	7.80 a	3.45	20.10	9.75	5.80	5.70	13.00 a	65.60 ab
	2-28	7.70 a	3.65	21.00	9.60	5.90	5.80	13.60 a	67.25 a
	2-36	7.50 a	3.15	19.20	7.95	5.20	5.00	10.60 b	58.60 b
CV (%)		23.14	26.82	28.95	26.60	28.30	32.85	23.72	19.13

Means within the same column with different common letters differ significantly by DMRT; * = $p<0.05$; ns=non-significant

4.11.2 Sensory evaluation in round 2

Once the selected treatment combinations in each subgroup that received the highest total wine appreciation scores from sensory testing in round 1 from subgroup P.1 to T.4, These combinations were sensory tested in round 2 to select the most optimal combination in each group from P to U (Table 4.19). The results were as follows;

Group P had selected combination 2-33 (total wine appreciation scores of 67.11) with non-significance.

Group Q had selected combination 2-25 (70.44).

Group R had selected combination 2-9 (67.06) with non-significance.

Group S had selected combination 2-39 (61.45) with non-significance.

Group T had selected combination 2-28 (68.55).

Group U had selected combination 2-24 (65.05).

Table 4.19: Wine appreciation chart of Krachai-Dam honey wines by sensory evaluation of 15-23 panelists in crop year 2005-2006 (round 2)

Groups	Treatment	Wine appreciation scores							
		Appearance (10)	Color (5)	Varietal aroma &bouquet (30)	Flavor (15)	Acidity (10)	Defect (10)	General quality (20)	Total (100)
P	2-31	8.22 a	3.44 ns	19.33 ns	8.50 ns	5.56 ns	4.78 ns	11.00 ns	60.89 ns
	2-33	8.89 a	3.50	21.33	9.67	5.78	6.22	11.78	67.11
	2-43	6.67 b	3.56	22.00	8.67	5.33	6.67	10.56	61.44
	2-44	7.00 b	3.56	21.00	9.33	5.89	5.44	11.78	64.00
	2-56	7.11 b	3.72	21.00	8.67	5.22	5.44	11.33	67.11
	CV (%)	16.99	23.60	24.70	26.15	31.63	32.86	30.70	19.96
Q	2-25	8.33 a	3.61 a	22.00 a	10.17 a	6.00 ns	6.22 ns	14.11 a	70.44 a
	2-57	4.33 b	2.61 b	16.67 b	5.33 b	4.44	4.11	8.11 b	45.61 b
	CV (%)	35.11	37.36	33.57	47.07	47.87	47.34	34.10	30.52
R	2-9	8.33 a	3.28 ns	20.67 ns	10.00 ns	5.89 ns	6.22 ns	12.67 ns	67.06 ns
	2-58	7.22 b	3.56	22.00	9.50	5.44	5.56	12.33	65.61
	CV (%)	16.75	22.21	23.18	27.16	21.90	28.53	24.62	19.13
S	2-39	7.60 ns	3.80 ns	17.40 ns	8.85 ns	5.90 ns	5.30 ns	12.60 ns	61.45 ns
	2-53	7.60	3.50	22.20	5.55	4.00	4.10	9.30	56.25
	CV (%)	24.15	36.16	28.32	32.98	38.75	48.22	26.92	19.83
T	2-7	8.40 a	3.80 a	20.70 ab	7.80 ns	5.60 ab	5.80 ns	13.00 ns	65.10 ab
	2-28	7.80 a	3.60 a	21.90 a	9.15	6.40 a	6.20	13.50	68.55 a
	2-35	6.60 b	2.65 b	18.00 bc	7.50	5.10 b	5.80	11.60	57.25 c
	2-48	7.90 a	3.75 a	16.80 c	7.80	5.20 b	5.30	12.20	58.95 bc
	CV (%)	19.36	23.04	26.38	28.37	27.48	26.22	19.99	16.89
U	2-32	5.60 b	2.90 b	15.90 b	7.65 ns	4.70 b	4.70 ns	9.80 bc	51.25 b
	2-23	7.20 a	3.55 a	20.70 a	7.65	5.20 ab	5.20	11.40 ab	60.90 a
	2-19	4.00 c	1.80 c	10.50 c	6.75	4.60 b	4.30	8.80 c	40.75 c
	2-24	7.80 a	3.90 a	20.70 a	8.55	6.10 a	5.60	12.40 a	65.05 a
	2-20	7.50 a	3.80 a	18.00 ab	7.65	6.10 a	5.00	10.60 abc	58.65 ab
	CV (%)	24.59	30.25	36.00	31.55	32.76	32.68	31.06	23.15

Means within the same column with different common letters differ significantly by DMRT; * = $p<0.05$; ns= non-significant

4.11.3 Sensory evaluation in round 3.

Once the selected treatment combinations in each group that received the highest total wine appreciation scores from sensory testing in round 2 from group P, Q and R, and group S, T and U (Table 4.20) were identified, it was found that Group PGR had the selected combination of 2-25 (total wine appreciation scores of 72.25) with non-significance, whereas Group RST had the selected combination of 2-28 (70.89) with non-significance.

Table 4.20: Wine appreciation chart of Krachai-Dam honey wines by sensory evaluation of 15-23 panelists in crop year 2005-2006 (round 3 and 4).

Groups	Treatment	Wine appreciation scores							
		Appearance (10)	Color (5)	Varietal aroma &Bouquet (30)	Flavor (15)	Acidity (10)	Defect (10)	General quality (20)	Total (100)
PQR	2-9	8.20 ns	3.35 b	21.90 ns	9.45 ns	6.10 ns	6.30 ns	13.40 ns	68.70 ns
	2-25	8.60	3.75 ab	22.50	10.20	6.40	6.30	14.50	72.25
	2-33	8.20	3.85 a	22.20	8.70	6.20	5.80	13.60	68.55
	CV (%)	11.55	17.71	15.95	23.13	21.54	24.35	18.36	13.71
STU	2-24	8.33 ns	3.28 b	20.00 ns	9.83 ns	6.56 ns	5.67 ns	14.11 ns	67.78 ns
	2-28	8.22	4.39 a	22.33	10.50	6.22	5.78	13.44	70.89
	2-39	7.67	4.22 a	20.00	8.83	5.78	5.67	12.44	64.61
	CV (%)	14.00	17.55	23.32	25.12	22.14	27.28	22.97	15.89
Best	2-25	9.18 ns	3.73 ns	21.82 ns	11.45 ns	7.09 ns	6.73 ns	15.27 ns	75.27 ns
	2-28	7.64	4.09	24.82	11.45	7.27	7.00	14.45	76.73
	CV (%)	14.62	25.29	22.98	17.15	13.47	23.16	19.18	12.12

Means within the same column with different common letters differ significantly by DMRT; * = $p<0.05$; ns= non-significant

4.11.4 Sensory evaluation in final round

Once the wine appreciation scores of the selected treatment combinations of group PQR and group STU from sensory testing by trained-panelists were compared, the final selected treatment combination of this research was treatment combination number 2-28 (wine produced from Krachai-Dam rhizomes with raw materials were grown at Maechonluang area (1,450 m asl) in May, harvested in February, with a 1 year crop growing storage period of 0 month after harvest and layout on the ground); this rendered a total wine appreciation score of 76.73. However, combination number 2-28 had higher non-significance than combination number 2-25 (wine produced from Krachai-Dam rhizomes with raw materials grown at Nakhonphanom area (200 m asl) in May, harvested in February, a 1 year crop growing, with a storage period of 0 month after harvest and layout an the ground), this rendered a total wine appreciation score of 75.27.

4.12 Selection of the most optimal Krachai-Dam honey wine processing using raw materials affected by factors studied.

The main criteria to select the most optimal Krachai-Dam honey wine processing were chemical and pharmaceutical qualities (TP and AOI) and wine appreciation through sensory testing. When we considered the chemical and pharmaceutical parameters, treatment combination number 2-28 gave a much higher TP (380.00 mg GAE/ 100 ml) and AOI (1.36) than combination number 2-25 (296.58 mg GAE/ 100 ml) and AOI (1.23). When we considered the wine appreciation scores from sensory testing, combination number 2-28 also gave a higher total wine appreciation score (76.73) than combination number 2-25 (75.27) with a non-significant difference. Therefore, this research concludes that treatment combination number 2-28 was the most optimal process (wine produced from Krachai-Dam rhizomes with raw materials grown at Maechonluang area in May, harvest in February, a 1 year crop growing, with a storage period of 0 month after harvest and keeping rhizomes by layout on the ground, at room temperature).

Part III Factors that influenced Krachai-Dam rhizomes used as raw materials for Krachai-Dam.

4.13. Quantitative yields

Quantitative yields of Krachai-Dam planted in crop season of 2004-2006 and 2005-2006 of each factor were studied and shown in Table 4.21. As for plantation area (factor 1), there were significant differences in 2 parameters studied, which were weight of rhizome and production per hectare. Krachai-Dam plants which were grown in Maechonluang area gave the highest weight of rhizome and production per hectare (38.52 g per rhizome and 3,977.81 kg per hectare respectively), whereas plants which were grown in Phrae area gave the lowest ones (22.21 g per rhizome and 2,133.38 kg per hectare respectively). As for year crops (factor 2), there were significant differences in 2 parameters. The plants, which were grown in 2-year crop (2004-2006), gave significantly higher weight of rhizome and production per hectare than the ones grown in 1-year crop (2005-2006).

Table 4.21 Quantitative yield of Krachai-Dam in year crops of 2004-2006 and 2005-2006 by each factor.

Factors	Quantitative yields of Krachai-Dam	
	Weight of rhizome (g)	Production per hectare (kg)
Areas (factor 1)		
Nakhonphanum	27.11 b	2,377.81 b
Phrae	22.21 c	2,133.38 b
Phurua	23.77 bc	2,340.75 b
Maechonluang	38.52 a	3.977.81 a
Year crops (factor 2)		
1-year crop	20.66 b	2,214.81 b
2-year crop	33.89 a	3,200.00 a

#Means within the same column with different common letters differ significantly by DMRT; * = $p<0.05$; ns=non-significant

When 2-factor combination was considered (Table 4.22), there were significant relation between the 2 factors studied on 2 parameters, which were weight of rhizome (16.42-44.23 g per rhizome) and production per hectare (1,792.63-4,740.75 kg per hectare). It was found that the combination of plants which were grown in Maechonluang area in 2-year crop gave the highest weight of rhizome and production per hectare (44.23 g per rhizome and 4,740.75 kg per hectare respectively), whereas the combination of plants grown in Phrae area and 1-year crop gave the lowest (16.42 g per rhizome and 1,792.63 kg per hectare respectively).

Table 4.22 Factor combinations between plantation areas and year crops on quantitative yields of Krachai-Dam in crop season of 2004-2006 and 2005-2006.

Factor combinations		Quantitative yields of Krachai-Dam	
Areas	Year crops	Weight of rhizome (g)	Production per hectare (kg)
Nakhonphanom	**1-year crop**	25.10 c	1,985.19 c
	2-year crop	31.75 b	2,770.38 bc
Phrae	**1-year crop**	16.42 d	1,792.63 c
	2-year crop	26.27 bc	2,474.06 bc
Phurua	**1-year crop**	20.28 cd	1,866.69 c
	2-year crop	25.27 c	2,814.81 bc
Maechonluang	**1-year crop**	21.39 cd	3,214.81 b
	2-year crop	44.23 a	4,740.75 a
CV%		**42.75**	**23.83**

#Means within the same column with different common letters differ significantly by DMRT; * = $p<0.05$; ns=non-significant

Therefore, the 'Maechonluang' area supplied the significantly highest quantitative yields. In addition, the 2-year crop showed higher yields than the 1-year crop.

4.14 Qualitative yields

4.14.1 Effects of plantation areas and harvesting months on qualitative yields of Krachai-Dam.

Qualitative attributes of Krachai-Dam rhizomes by each factor are shown in Table 4.23. As for plantation area (factor 1), there were significant difference in all parameters studied. TP, AOI and a* increased as the elevation level of plantation area was higher, whereas L* decreased. As for harvesting month (factor 2), there were significant differences in all parameters studied. The rhizomes which were harvested in

January and December (8 and 7 months after growing respectively) gave the highest AOI and TP, but gave the lowest b*, whereas rhizomes which were harvested in November gave the lowest AOI, TP and L*.

Table 4.23 Effects of plantation areas and harvesting months on qualitative yields of Krachai-Dam.

Factors	Physical and chemical qualities of rhizomes				
	Internal color of rhizomes			Total phenolic compounds[2]	Anti-oxidant index[3]
	L*	a*	b*		
Plantation areas (Factor 1)					
Nakhonphanum	37.06 a	7.21 c	4.21 b	48.96 d	1.35 d
Phrae	35.99 b	7.17 c	2.48 c	58.08 c	1.38 c
Phurua	34.53 c	12.09 b	3.98 b	61.06 b	1.42 b
Maechonluang	34.30 c	13.15 a	4.87 a	65.97 a	1.47 a
Harvesting months (Factor 2)					
November	34.66 b	9.90 b	4.69 a	52.92 d	1.30 c
December	35.33 ab	11.11 a	3.54 b	61.32 ab	1.45 a
January	35.84 a	9.43 c	3.36 b	61.95 a	1.45 a
February	35.84 a	10.20 b	3.06 b	60.53 b	1.44 a
March	36.01 a	8.65 d	4.97 a	55.88 c	1.40 b

Means within the same column with different common letters differ significantly by DMRT; * = $p<0.05$; ns=non-significant
[1] Total titrable acidity showed in form of citric acid (g/l)
[22]Total phenolic compounds showed in form of Gallic acid equivalent (mg/ ml of ethanolic extracts)
[3] Antioxidant index must be ≥1, if <1 showed that no antioxidative activity.

When 2-factor combination was considered (Table 4.24), there were significant relations between the 2 factors studied on all parameters, which were TP, AOI, L*, a* and b* (41.93-69.38 mg/ml of extracts, 1.25-1.51, 30.03-38.61, 5.82-14.48 and -1.15-7.69 respectively).

Table 4.24 Effects of factor combinations in experiment 3.1 on qualitative yields of Krachai-Dam.

Factor combinations		Physical and chemical qualities of rhizomes				
		Internal color of rhizomes			Total phenolic compounds[2]	Anti-oxidant index[3]
Areas	Harvesting months	L*	a*	b*		
Nakhonphanom	November	36.56 bc	7.29 j	5.74 b	41.93 h	1.25 i
	December	36.19 bcd	8.62 h	3.10 fghi	51.17 f	1.39 def
	January	36.77 abc	8.25 hi	5.86 b	52.12 f	1.39 def
	February	38.61 a	6.06 k	3.02 ghi	51.12 f	1.38 efg
	March	37.06 ab	5.82 k	4.06 defgh	48.48 g	1.36 fg
Phrae	November	35.46 bcdef	6.45 k	4.53 bcdef	55.45 e	1.29 h
	December	35.78 bcde	7.61 ij	-1.15 k	60.60 c	1.44 bc
	January	37.01 ab	8.84 h	0.78 j	61.32 c	1.43 cd
	February	35.32 bcdef	7.71 ij	1.96 ij	58.40 d	1.41 cde
	March	36.46 bc	5.92 k	3.84 defgh	54.65 e	1.34 g
Phurua	November	33.13 g	11.33 g	5.04 bcd	56.12 e	1.26 hi
	December	34.71 cdefg	12.11 def	4.82 bcde	64.50 b	1.49 a
	January	33.50 fg	11.58 fg	1.73 ij	64.97 b	1.48 a
	February	35.63 bcde	12.77 cd	2.69 hi	63.73 b	1.47 ab
	March	36.29 bcd	12.99 bc	3.50 efgh	55.97 e	1.39 def
Machonluang	November	34.41 defg	12.62 cde	3.66 defgh	58.18 d	1.38 efg
	December	34.99 bcdefg	13.59 b	4.20 cdefg	69.00 a	1.49 a
	January	33.03 g	12.03 ef	3.62 defgh	69.38 a	1.50 a
	February	33.77 efg	14.48 a	4.53 bcdef	68.88 a	1.51 a
	March	34.37 defg	12.26 def	7.69 a	64.42 b	1.49 a
CV%		11.80	12.20	81.37	2.10	2.25

Means within the same column with different common letters differ significantly by DMRT; * = $p<0.05$; ns=non-significant
[1] Total titrable acidity showed in form of citric acid (g/l)
[2] Total phenolic compounds showed in form of Gallic acid equivalent (mg/ ml of ethanolic extracts)
[3] Antioxidant index must be ≥1, if <1 showed that no antioxidative activity.

The most important qualities (TP and AOI) of rhizomes were considered. As for TP, it was found that the treatment combinations of Maechonluang area and harvesting month in January, December and February (8, 7 and 9 months after growing respectively) gave the highest of TP (69.38, 69.00 and 68.88 mg/ml of extracts respectively). As for AOI, the combinations of Maechonluang area and harvesting month in February, January, March and December (9, 8, 10 and 7 months after growing respectively) and combinations of Phurua area and harvesting month in December, January and February (7, 8 and 9 months after growing respectively) gave the highest AOI (1.51, 1.50, 1.49, 1.49, 1.49, 1.48 and 1.47 respectively); whereas the combination of Nakhonphanom area and harvesting month in November (6 months after growing) gave the lowest TP and AOI (41.93 mg/ml of extracts and 1.25 respectively).

4.14.2 Effects of plantation area and planting month on qualitative yields of Krachai-Dam.

Qualitative attributes of Krachai-Dam rhizomes by each factor are shown in Table 4.25. As for plantation area (factor 1), there were significant differences in 5 parameters studied, which were L*, a* and b*, TP and AOI. TP, AOI and a* of Krachai-Dam rhizomes increased as the elevation level of plantation area was higher, whereas L* decreased. As for plantation time (factor 2), there were significant differences in 3 parameters studied, which were TP, AOI and b*. The rhizomes which were grown in May and June gave the higher TP and AOI than one grown in July, whereas rhizomes which were grown in July gave the higher b* than May.

Table 4.25 Effects of plantation areas and planting months by each factor.

Factors	Physical and chemical qualities of rhizomes				
	Internal color of rhizomes			Total phenolic compounds[2]	Anti-oxidant index[3]
	L*	a*	b*		
Plantation Areas (factor 1)					
Nakhonphanom	36.76 a	8.48 b	6.23 a	51.52 d	1.37 c
Phrae	38.11 a	8.84 b	1.38 d	61.18 c	1.42 b
Phurua	33.53 b	11.94 a	4.48 b	64.51 b	1.48 a
Maechonluang	33.90 b	11.54 a	2.93 c	67.79 a	1.49 a
Planting months (factor 2)					
May	35.87 ns	9.44 ns	3.48 b	61.95 a	1.45 a
June	35.16	10.42	4.24 ab	61.63 a	1.45 a
July	35.81	10.31	4.75 a	60.18 b	1.42 b

Means within the same column with different common letters differ significantly by DMRT; * = $p<0.05$; ns=non-significant
[1] Total titrable acidity showed in form of citric acid (g/l)
[2] Total phenolic compounds showed in form of Gallic acid equivalent (mg/ ml of ethanolic extracts)
[3] Antioxidant index must be ≥1, if <1 showed that no antioxidative activity.

When 2-factor combination was considered (Table 4.26), there were significant relations between the 2 factors studied on only one parameter, which was L* (31.02-41.93).

The most important qualities (TP and AOI) of rhizomes were considered. It was found that the treatment combination of Maechonluang area with a planting month in May and June rendered the highest of AOI and TP (1.50 and 1.50; 69.38 and 67.35 mg/ml extract respectively) with non-significant difference, whereas the combination of Nakhonphanom area with planting month in July gave the lowest of TP (50.52 mg/ml extract) and AOI (1.33).

Table 4.26 Factor combination between plantation areas and planting months on qualitative yields of Krachai-Dam.

Factor combinations		Internal color of rhizomes			Total phenolic compounds[2]	Anti-oxidant index[3]
Plantation areas	Planting months	L*	a*	b*		
Nakhon phanom	May	36.86 b	8.25 c	5.86 a	52.12 h	52.12 h
	June	36.94 b	8.59 c	6.03 a	51.92 h	51.92 h
	July	36.33 bcd	8.67 bc	7.10 a	50.52 i	50.52 i
Phrae	May	37.01 b	8.84 bc	0.78 d	61.32 fg	61.32 fg
	June	36.50 bc	8.21 c	1.73 cd	61.90 ef	61.90 ef
	July	41.93 a	9.47 b	2.24 cd	60.32 g	60.32 g
Phurua	May	33.50 cde	11.58 a	1.73 cd	64.97 d	64.97 d
	June	33.31 de	12.07 a	4.98 ab	65.33 cd	65.33 cd
	July	34.22 bcde	11.90 a	5.75 a	63.22 e	63.22 e
Maechonluang	May	33.03 e	12.03 a	3.62 bc	69.38 a	69.38 a
	June	34.78 bcde	11.35 a	2.54 cd	67.35 b	67.35 b
	July	33.02 e	11.58 a	3.16 bc	66.65 bc	66.65 bc
CV%		6.18	13.65	104.75	3.53	1.26

Means within the same column with different common letters differ significantly by DMRT; * = $p<0.05$; ns= non-significant
[1] Total titrable acidity showed in form of citric acid (g/l)
[2] Total phenolic compounds showed in form of Gallic acid equivalent (mg/ ml of ethanolic extracts)
[3] Antioxidant index must be ≥1, if <1 showed that no antioxidative activity.

4.14.3 Effects of plantation areas and number of year crops on qualitative yields of Krachai-Dam.

Qualitative attributes of Krachai-Dam rhizomes by each factor are shown in Table 4.27. As for plantation area (factor 1), there were significant differences in all parameters studied. TP, AOI and a* of rhizomes increased as the elevation level of plantation area was higher, whereas L* and b* decreased. As for year crop numbers (factor 2), there were significant differences in only one parameter which was a*. The rhizomes which were grown in 2-year crop rendered higher a* than the one grown in 1-year crop.

Table 4.27 Effects of plantation areas and number of year crops on qualitative yields of Krachai-Dam.

Factor	Physical and chemical qualities of rhizomes				
	Internal color of rhizomes			Total phenolic compounds[2]	Anti-oxidant index[3]
	L*	a*	b*		
Plantation areas (factor 1)					
Nakhonphanom	37.00 a	9.39 d	5.43 a	52.60 d	1.40 c
Phrae	35.88 ab	9.98 c	0.89 c	61.18 c	1.42 b
Phurua	32.64 c	11.97 b	1.38 c	61.85 b	1.49 a
Machonluang	34.74 b	12.67 a	4.35 b	69.42 a	1.51 a
Year crops (factor 2)					
1- year crop	35.60 ns	9.43 a	3.47 ns	61.94 ns	1.45 ns
2- year crop	34.50	12.50 a	2.88	61.56	1.46

Means within the same column with different common letters differ significantly by DMRT; * = $p<0.05$; ns= non-significant
[1] Total titrable acidity showed in form of citric acid (g/l)
[2] Total phenolic compounds showed in form of Gallic acid equivalent (mg/100 ml of wines)
[3] Antioxidant index must be ≥1, if <1 showed that no antioxidative activity.

When 2-factor combination was considered (Table 4.28), there were significant relations between the factors studied on one parameter which was a* (8.25-12.89).

Table 4.28 Effects of factor combinations in experiment 3.3 on qualitative yields of Krachai-Dam.

Factor combinations		Physical and chemical qualities of rhizomes				
		Internal color of rhizomes			Total phenolic	Anti-oxidant
Areas	Year crops	L*	a*	b*	compounds[2]	index[3]
Nakhonphanom	1- year crop	36.77 ns	8.25 c	5.80 ns	52.12 d	1.39 ns
	2- year crop	37.71	12.83 a	4.34	53.08 d	1.41
Phrae	1- year crop	37.01	8.84 c	0.78	61.32 c	1.43
	2- year crop	35.23	12.24 ab	1.13	61.05 c	1.42
Phurua	1- year crop	33.50	11.58 b	1.73	64.97 b	1.48
	2- year crop	32.36	12.10 ab	1.27	62.65 c	1.48
Machonluang	1- year crop	33.03	12.03 ab	3.62	69.38 a	1.50
	2- year crop	35.31	12.89 a	4.60	69.45 a	1.51
CV%		15.93	11.72	72.84	1.51	1.15

Means within the same column with different common letters differ significantly by DMRT; * = $p<0.05$; ns=non-significant
[1] Total titrable acidity showed in form of citric acid (g/l)
[2] Total phenolic compounds showed in form of Gallic acid equivalent (mg/ ml of ethanolic extracts)
[3] Antioxidant index must be ≥1, if <1 showed that no antioxidative activity.

The most important qualities (TP and AOI) of rhizomes were considered. It was found that there were no significant differences between these, but there was a trend thereby the treatment combination of Maechonluang area, grown in 2-year crop, would give the highest of AOI (1.51), whereas the combination of Nakhornphanom area, grow in 1-year crop gave the lowest (1.39). Moreover, the combination of Maechonluang area, grown in 1 and 2 year crop, gave the highest of TP (69.48 and 69.45 mg/ml of ethanol extract), whereas the combination of Nakhornphanom area, grown in 1 year crop, gave the lowest one (52.12 mg/ml of extract).

4.14.4 Effects of (a) plantation areas, (b) storage periods and (c) storage methods on qualitative yields of Krachai-Dam

Qualitative attributes of Krachai-Dam rhizomes by each factor are shown in Table 4.29. As for plantation are (factor 1), there were significant differences in all parameters studied, which were TP, AOI, weight loss, L*, a* and b*. TP, AOI and a* of rhizomes increased as the elevation level of plantation area was higher, whereas L* and b* decreased. As for storage period (factor 2), there were significant differences in all parameters except the b*. TP and AOI of rhizomes increased as the storage period was longer, whereas L* and weight loss decreased. As for storage method (factor 3), there were significant differences in all parameters except the a*. The cold storage method gave the highest TP and AOI, but rendered the lowest L*, b* and weight loss. Layout on the ground and keeping net bags gave similar results, in all parameters except b*.

Each pair of factor combinations was considered (Table 4.30). The effects of 2-factor combinations of 3-factors, which were plantation areas (factor 1), storage periods (factor 2) and storage methods (factor 3) of rhizomes, were studied. There were significant relation between the 2-factor combination of plantation area (factor 1) and storage period (factor 2) in all parameters of rhizome qualities. As for rhizome color, the combination of Nakhonphanom and Phrae area and storage period of 6 months after harvest gave the highest L* (40.69 and 40.50 respectively), whereas the combination of Phurua and Maechonluang area and storage period of 0 month after

harvest gave the lowest ones (33.50 and 33.03 respectively). The combination of Phrae and Maechonluang areas and storage period of 3 months after harvest gave the highest a* (13.27 and 13.05 respectively), whereas the combination of Nakhonphanom area and storage period of 0 month after harvest gave the lowest one (8.25). The combination of Nakhonphanom area and storage period of 6 months after harvest gave the highest b* (6.85), whereas the combination of Maechonluang and 3 months after harvest gave the lowest one (-0.82). As for weight loss, the combination of all areas and storage period of 6 month after harvest gave the highest weight loss (21.86-24.39%), whereas the combination of all areas and storage period of 0 month after harvest gave the lowest one (0.00%). As for TP and AOI, the combination of Maechonluang area and storage period of 0 months after harvest gave the highest TP and AOI (69.48 mg/ml of extracts and 1.50 respectively), whereas the combination of Nakhonphanom area and storage period of 6 months after harvest gave the lowest ones (42.18 mg/ml of extracts and 1.14 respectively).

Table 4.29 Effects of plantation areas, storage periods, and methods on qualitative yields of Krachai-Dam.

Factors	Physical and chemical qualities of rhizomes					
	Internal color of rhizomes			Weigth loss	Total phenolic compounds[2]	Anti-oxidant index[3]
	L*	a*	b*			
Areas (factor 1)						
Nakhonphanom	37.56 a	9.80 d	5.85 a	12.14 a	46.75 d	1.29 d
Phrae	38.16 a	11.04 c	1.48 c	11.80 a	54.70 c	1.34 c
Phurua	35.22 b	11.40 b	2.45 b	9.63 b	60.20 a	1.39 a
Machonluang	35.40 b	12.16 a	1.93 bc	12.88 a	57.78 b	1.38 b
Storage periods (factor 2)						
0 month	35.84 c	9.43 c	3.43 b	0.00 c	61.96 a	1.45 a
3 month	36.92 b	12.57 a	1.46 c	13.38 b	55.42 b	1.41 b
6 month	38.98 a	11.40 b	5.34 a	21.46 a	47.19 c	1.20 c
Storage methods (factor 3)						
Layout	37.62 a	10.79 ns	3.51 a	15.68 a	52.42 b	1.31 b
Net bag	37.04 a	10.85	3.69 a	15.69 a	52.35 b	1.31 b
Cool	36.03 b	11.06	2.49 b	5.13 b	59.81 a	1.43 a

Means within the same column with different common letters differ significantly by DMRT; * = $p<0.05$; ns=non-significant
[1] Total titrable acidity showed in form of citric acid (g/l)
[2] [2] Total phenolic compounds showed in form of Gallic acid equivalent (mg/ ml of ethanolic extracts)
[3] Antioxidant index must be ≥1, if <1 showed that no antioxidative activity.

The effects of 2-factor combination of plantation area (factor 1) and storage method (factor 3) of rhizomes showed that there were significant relations between the 2 factors in all parameters studied. As for rhizome color, the combination of Phrae area and layout on the ground and keeping in net bags gave the highest b* (38.84 and 38.56), whereas the combination of Phurua and Maechonluang areas and cold storage gave the lowest ones (34.44 and 34.46). The combination of Maechonluang area and cold storage gave the highest a* (12.36), whereas the combination of Nakhonphanom area and cold storage gave the lowest one (8.75). The combination of Nakhonphanom area and all storage methods gave the highest b* (5.56-6.19), whereas Nakhonphanom and Phurua areas and cold storage gave the lowest ones (0.56 and 1.27 respectively). As for weight loss, the combination of Maechonluang, Phurua, Nakhonphanom and Phrae areas and layout on the ground and keeping in net bags gave higher weight loss (14.76-17.01) than other combinations. As for TP and AOI, the combination of Maechonluang area and cold storage gave the highest TP and AOI (68.07 mg/ml of

extracts and 1.48 respectively), whereas the combination of Nakhonphanom area and layout on the ground and keeping in net bags gave the lowest ones (45.20 and 45.12 mg/ml of extracts; and 1.25 and 1.26 respectively).

Table 4.30 Effects of each pair of factor combinations in experiment 3.4 on factors (plantation area, storage periods, and storage methods) on qualitative yields of Krachai-Dam.

Factor combinations		Physical and chemical qualities of rhizomes					
		Internal color of rhizomes			Weight loss	Total phenolic compounds[2]	Anti-oxidant index[3]
Plantation Area	Methods	L*	a*	b*			
Nakhonphanom	Layout	38.25 ab	9.99 d	5.72 a	15.51 a	45.20 e	1.25 c
	Net bag	37.51 abc	10.37 d	6.19 a	15.75 a	45.12 e	1.26 c
	Cool	36.67 bcde	8.75 e	5.56 a	5.16 b	49.92 de	1.36 abc
Phrae	Layout	38.84 a	10.50 d	2.00 bc	14.76 a	52.92 cd	1.31 bc
	Net bag	38.56 a	10.39 d	2.03 bc	15.70 a	52.85 cd	1.31 bc
	Cool	37.25 abcd	12.05 ab	0.56 c	4.93 b	58.34 bc	1.42 ab
Phurua	Layout	35.96 cdef	11.47 bc	3.00 b	14.76 a	55.13 bcd	1.33 bc
	Net bag	35.22 ef	11.24 c	3.02 b	15.03 a	55.30 bcd	1.34 abc
	Cool	34.44 f	11.49 bc	1.27 c	5.08 b	62.89 ab	1.48 a
Maechonluang	Layout	36.12 cdef	12.10 ab	1.79 bc	17.01 a	56.41 bcd	1.35 abc
	Net bag	35.60 def	12.02 ab	1.77 bc	16.29 a	56.12 bcd	1.34 abc
	Cool	34.46 f	12.36 a	2.23 bc	5.35 b	68.07 a	1.48 a
Plantation Areas	Times						
Nakhonphanom	0 month	36.77 bc	8.25 h	5.71 ab	0.00 c	52.12 de	1.39 bc
	3 month	36.44 bc	11.90 bcd	5.22 b	13.28 b	45.94 fg	1.35 c
	6 month	40.69 a	11.48 de	6.85 a	23.14 a	42.18 g	1.14 e
Phrae	0 month	37.01 bc	8.84 g	0.78 d	0.00 c	61.27 bc	1.43 abc
	3 month	38.15 b	13.27 a	0.53 de	12.28 b	56.20 cd	1.41 abc
	6 month	40.50 a	12.10 b	4.30 bc	23.12 a	46.64 fg	1.20 de
Phurua	0 month	33.50 d	11.58 cde	1.73 d	0.00 c	64.98 ab	1.48 ab
	3 month	35.88 c	11.37 e	1.62 d	13.71 b	58.93 c	1.42 abc
	6 month	36.90 bc	11.19 e	4.35 bc	26.86 a	49.42 ef	1.24 d
Maechonluang	0 month	33.03 d	12.03 bc	3.62 c	0.00 c	69.48 a	1.50 a
	3 month	36.62 bc	13.05 a	-0.82 e	14.25 b	60.59 bc	1.44 abc
	6 month	36.12 c	10.52 f	5.25 b	24.39 a	50.53 ef	1.23 de
Times	Methods						
0 month	Layout	35.84 c	9.43 d	3.36 b	0.00 f	61.98 a	1.45 a
	Net bag	35.84 c	9.43 d	3.47 b	0.00 f	61.98 a	1.45 a
	Cool	35.84 c	9.43 d	3.47 b	0.00 f	61.98 a	1.45 a
3 month	Layout	37.51 b	12.41 ab	1.91 cd	16.93 c	53.28 b	1.39 b
	Net bag	36.50 bc	12.46 ab	1.55 cd	17.34 c	52.72 b	1.38 b
	Cool	36.73 bc	12.90 a	0.83 d	5.87 e	60.25 a	1.45 a
6 month	Layout	41.09 a	11.06 c	6.02 a	30.12 a	42.00 c	1.09 c
	Net bag	40.05 a	11.22 c	7.12 a	29.73 a	42.34 c	1.11 c
	Cool	35.52 c	11.98 b	2.66 bc	9.52 d	57.23 ab	1.40 b
CV%		5.86	11.24	123.79	17.04	3.94	1.19

Means within the same column with different common letters differ significantly by DMRT; * = $p<0.05$; ns= non-significant

[1] Total titrable acidity showed in form of citric acid (g/l)

[2] Total phenolic compounds showed in form of Gallic acid equivalent (mg/ ml of ethanolic extracts)

[3] Antioxidant index must be ≥1, if <1 showed that no antioxidative activity.

It was found that the effects of 2-factor combinations between storage period (factor 2) and storage method (factor 3) of rhizomes had significant relations between the 2 factors in all parameters studied. As for rhizome color, the combination of storage period of 6 months after harvest and layout on the ground and keeping in net bags gave the highest L* (41.09 and 41.05 respectively) and b* (6.02 and 7.12 respectively) but gave the lowest a* (11.06 and 11.22 respectively), whereas the combination of storage period of 0 month after harvest and layout on the ground and keeping in net bags gave the lowest L* (35.84 and 35.84 respectively) and a* (9.43 and 9.43 respectively). The combination of storing time of 3 months after harvest and cold storage gave the lowest b* (0.83). As for weight loss, the combination of storage period of 6 months after harvest and layout on the ground and keeping in net bags gave the highest weight loss (30.12 and 29.73% respectively), whereas the combination of storage period of 0 month after harvest and all storage methods gave the lowest ones (0.00%). As for TP and AOI, the combinations of storage period of 0

month after harvest and all storage methods, and the combination of storage period of 3 months after harvest and cold storage gave the highest TP and AOI (61.97, 61.98, 61.93 and 60.25 mg/ml of extracts; and 1.45, 1.45, 1.45 and 1.45 respectively).

Table 4.31 Effects of factor combinations in experiment 3.4 on qualitative yields of Krachai-Dam.

Factor combinations			Physical and chemical qualities of rhizomes					
			Internal color of rhizomes					
Plantation areas	Storage periods	Storage methods	L*	a*	b*	Weight loss	Total phenolic compounds[2]	Anti-oxidant index[3]
Nakhon phanom	0 month	Layout	36.77 def	8.25 l	5.55 bcd	0.00 f	52.12 h	1.39 g
		Net bag	36.77 def	8.25 l	5.80 bcd	0.00 f	52.12 h	1.39 g
		Cool	36.77 def	8.25 l	5.80 bcd	0.00 f	52.12 h	1.39 g
	3 month	Layout	37.33 def	11.87 def	5.55 bcd	16.78 c	43.50 jk	1.32 h
		Net bag	35.58 defgh	12.98 bc	5.45 bcd	17.61 c	43.60 jk	1.33 h
		Cool	36.41 defg	9.79 k	4.09 cdef	5.46 de	50.72 h	1.39 fg
	6 month	Layout	42.14 b	11.61 efg	6.24 bc	29.76 ab	39.98 l	1.04 m
		Net bag	40.92 bc	11.98 def	7.70 ab	29.64 ab	39.65 l	1.06 l
		Cool	36.52 defg	9.92 jk	6.25 bc	10.04 d	46.92 i	1.31 h
Phrae	0 month	Layout	37.01 def	8.84 l	0.78 ghi	0.00 f	61.32 d	1.43 de
		Net bag	37.01 def	8.84 l	0.78 ghi	0.00 f	61.32 d	1.43 de
		Cool	37.01 def	8.84 l	0.78 ghi	0.00 f	61.17 d	1.43 de
	3 month	Layout	38.21 cde	12.97 bc	0.78 ghi	15.15 c	55.43 fg	1.41 efg
		Net bag	37.42 def	12.66 cd	-0.28 hi	16.60 c	54.75 g	1.40 efg
		Cool	38.81 cd	14.18 a	1.08 ghi	5.08 e	58.42 e	1.42 def
	6 month	Layout	45.01 a	10.01 jk	7.69 ab	29.14 ab	42.02 k	1.09 k
		Net bag	44.98 a	10.01 jk	10.00 a	30.50 ab	42.48 jk	1.10 jk
		Cool	36.01 defgh	14.20 a	-0.24 hi	9.71 de	55.43 fg	1.40 efg
Phurua	0 month	Layout	33.50 gh	11.58 efg	1.73 fgh	0.00 f	64.97 bc	1.48 ab
		Net bag	33.50 gh	11.58 efg	1.73 fgh	0.00 f	64.97 bc	1.48 ab
		Cool	33.50 gh	11.58 efg	1.73 fgh	0.00 f	64.97 bc	1.48 ab
	3 month	Layout	36.33 defg	11.18 fgh	2.04 fgh	17.53 c	56.97 ef	1.39 fg
		Net bag	35.62 defgh	10.85 ghi	2.88 defg	17.19 c	56.43 efg	1.38 g
		Cool	35.71 defgh	12.12 de	-0.15 hi	6.42 de	63.40 c	1.48 ab
	6 month	Layout	38.88 cd	11.63 efg	5.67 bcd	28.84 ab	43.47 jk	1.11 jk
		Net bag	37.09 def	11.22 fgh	4.90 bcde	27.89 b	44.47 j	1.15 i
		Cool	34.41 fgh	10.64 hij	2.21 efgh	8.84 de	60.32 d	1.46 bc
Maechonluang	0 month	Layout	33.03 h	12.03 def	3.62 cdefg	0.00 f	69.48 a	1.50 a
		Net bag	33.03 h	12.03 def	3.62 cdefg	0.00 f	69.48 a	1.50 a
		Cool	33.03 h	12.03 def	3.62 cdefg	0.00 f	69.48 a	1.51 a
	3 month	Layout	37.58 def	12.98 bc	-0.67 hi	18.27 c	57.20 e	1.43 de
		Net bag	36.95 def	12.57 cd	-1.25 i	17.96 c	56.10 fg	1.41 efg
		Cool	35.33 efgh	13.58 ab	-0.56 hi	6.52 de	68.47 a	1.49 a
	6 month	Layout	37.29 def	10.43 hijk	4.26 cdef	32.75 a	42.55 jk	1.12 j
		Net bag	36.34 defg	10.91 ghi	5.32 bcd	30.91 ab	42.77 jk	1.11 jk
		Cool	34.64 fgh	10.21 ijk	6.22 bc	9.52 de	66.27 b	1.45 cd
	CV%		5.86	11.24	123.79	17.04	3.94	1.19

Means within the same column with different common letters differ significantly by DMRT; * = $p<0.05$; ns=non-significant

[1] Total titrable acidity showed in form of citric acid (g/l)

[2] Total phenolic compounds showed in form of Gallic acid equivalent (mg/ ml of ethanolic extracts)

[3] Antioxidant index must be ≥1, if <1 showed that no antioxidative activity.

When 3-factor combination was considered (Table 4.31), there were significant relations among the 3 factors studied in all parameters which were L*, a*, b*, weight loss, TP and AOI (33.03-45.01, 8.25 -14.18, -1.25-10.00, 0.00-32.75%, 42.02-69.48 mg/ml of extracts, and 1.09-1.50 respectively).

The most important Krachai-Dam rhizomes qualities considered were TP and AOI of rhizomes. The following was found. As for TP, the combination of Maechonluang area, storage period of 0 month after harvest and all storage methods gave the highest TP (69.48 mg/ml of extracts), which were non significantly higher than the combination of Maechonluang area, storage period of 3 months after harvest and cold storage (68.47 mg/ml of extracts). However, the combination of Nakhonphanom area, storage period of 6 months after harvest and layout on the

ground and keeping in net bags gave the lowest ones (39.98 and 39.65 mg/ml of extracts respectively). As for AOI, the combination of Maechonluang area, storage period of 0 month after harvest and all storage methods gave the highest AOI (1.50), which were non significantly higher than the combination of Maechonlung area, storage period of 3 months after harvest and cold storage (1.49) and the combinations of Phurua area, storage period of 0 month after harvest and all storage methods (1.48). However, the combination of Nakhonphanom area, storage period of 6 months after harvest and layout on the ground gave the lowest one (1.04).