Survey of honey bee winter weight loss rates for Apis mellifera hives in USA, Europe and Japan

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Summary

Winter weight loss rates were obtained from hive weight data in journal and Internet sources. Values for 51 hives in UK, USA, Norway, Latvia, France, Germany, Belgium and Japan, ranged from 0.013 to 0.118 kg/day. The sampling was neither randomised nor exhaustive. The weight loss rates showed a complex distribution with an average of 0.054 kg/day, which, if entirely made up by loss in weight of honey stores, corresponds to a 1 October to 1 April consumption of 9.8 kg.

Introduction

The amount of honey consumed by colonies in winter depends on a number of factors:

- bee race
- winter brood rearing
- colony size
- climate and microclimate
- hive thermal loss (shape, wall thickness, wall composition, insulation, mesh floors, entrance area etc.)

Not unexpectedly the weights of honey consumed in various situations varies very widely. The following paper attempts to summarise data from both peer reviewed papers and websites reporting hive weight data, many of them resulting from continuous monitoring. Data only for a substantial span of winter months was chosen, the ideal span being from 1 October to 1 April or thereabouts.

Data from apiological and apicultural journal papers

From Fig. 4 in Villa et al. (2009) Russian bees from 2001-2004 in Iowa consumed on average 7.7 kg between November and April each winter. Assuming the precise dates were 1 Nov & 1 April (150 days), the daily consumption was 0.047 kg/day. Hives with mesh floors consumed 7.3 kg whereas with solid floors it was 5.9 kg. Thus a mesh floor caused a 24% increase in weight loss. No temperature data are given.

Guzman et al. (2005) found that from 10 November 1999 to 17 April 2000 (158 days) in Iowa, Italian colonies lost an average of 6.82 ± 0.34 kg whereas Russians lost only 3.93 ± 0.34. The corresponding daily weight losses are 0.043 and 0.025 kg. Winter temperatures ranged from 18 to -9.5°C. The average temperature from October to March was 3.5°C.

Meikle et al. (2008) published graphically the results of their continuous weight monitoring of colonies of unspecified race near Montpellier in the south of France. The data in the following table have been interpolated from their Fig. 2 and losses calculated.

Start date	Finish date	Start weight	Finish weight	Days	Weight loss	kg/day
15 Oct	15 Mar	27.7	16.7	145	11.0	0.076
15 Oct	15 Mar	25.5	13.9	145	11.6	0.079
15 Oct	26 Feb	25.5	14.9	128	10.6	0.082
15 Oct	26 Feb	22.4	12.2	128	10.2	0.080
13 Jan	15 Mar	14.4	8.9	61	5.5	0.090
13 Jan	15 Mar	23.0	15.8	61	7.2	0.118
					Average	**0.088**

October to March average monthly temperatures for Montpellier range from 7 to 16°C, averaging 10°C. Taking the overall average daily weight loss from mid-October to mid-March as 0.088 kg/day, the overall winter loss in that period was 12.8 kg.

In a study from December to February 2007 in Japan with Apis mellifera, Ohashi et al. (2008) reported a 'continuous' weight loss rate of 0.03 kg/day.

Olszewski (2007) reported winter food consumption [in kilograms] per colony between 1 November and 21 March (141 days) in Poland by Buckfast and Norwegian x Caucasian bees exposed to different overwintering methods (data from 2004 and 2005 winter were pooled together). Data from his Table 4 are shown here:

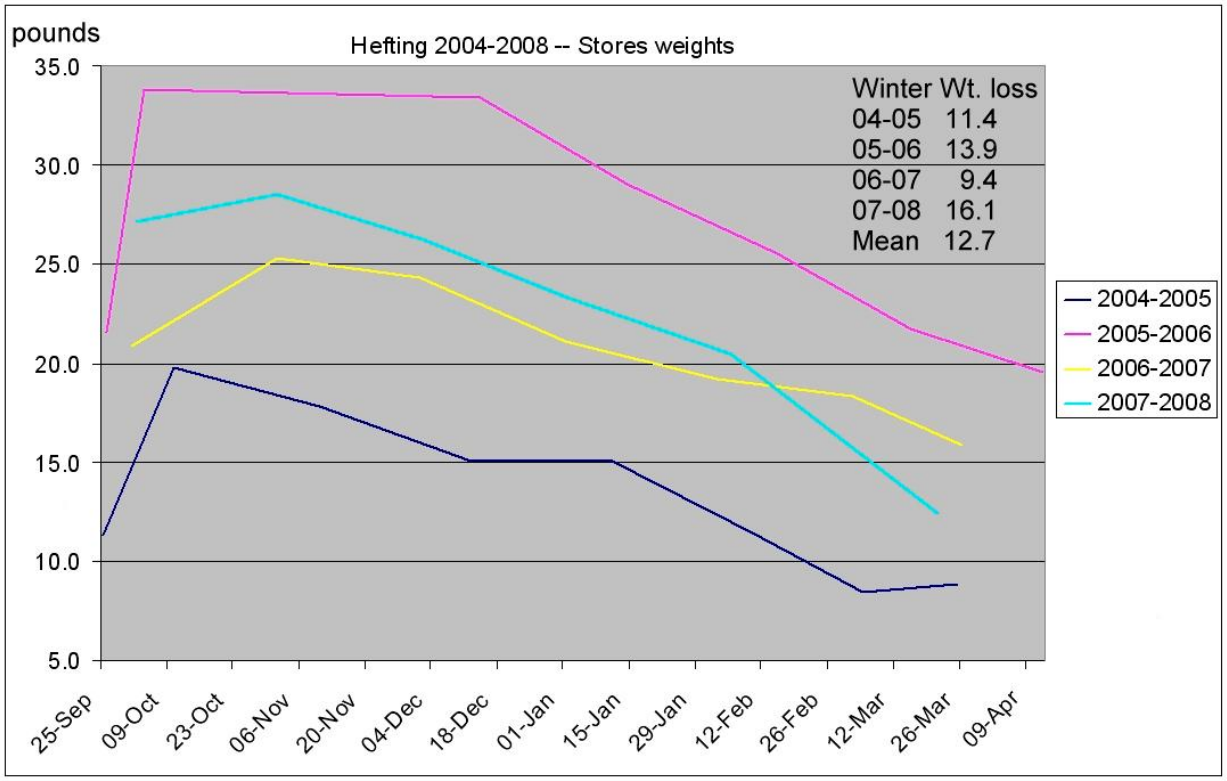
Overwintering method	Buckfast		Norwegian x Caucasian	
	Mean	CV	Mean	CV
Uninsulated	11.72	3.01	9.7	15.03
Insulated	9.72	17.63	7.8	25.59

Taking the average of the breeds, the consumption rates were 0.076 kg/day for uninsulated hives and 0.062 kg/day for insulated hives. In the study period, minimum temperatures ranged from +1 to -7°C. From the maximum and minimum temperatures given for November to February the average was calculated as 0.43°C.

Stalidzans et al. (2017) studied weight loss from 14 December to 21 March (99 days) within and outside a temperature controlled (4-6°C) hive wintering building in Latvia. Indoors, uninsulated colonies lost 3.5 ± 0.23 kg whereas uninsulated colonies lost 3.6 ± 0.41 kg. The outdoor colonies were all insulated and lost 5.2 ± 0.43 kg. The corresponding weight loss rates were 0.035, 0.036 and 0.052 kg/day. The outdoor temperature fell to -20°C in February and returned to around zero in March. Interpolating in Stalidzans' Fig. 2, the average through the period of the experiment was -2.6°C.

Data from Internet sources

This author monitored an average of 10 National (single brood box) colonies over four successive winters (2004-2008) in North-West Wales. Data for all hives through one winter are illustrated at http://www.dheaf.plus.com/beekeeping_photos/stores.jpg. Averages for the four winters are shown in the following figure.



The initial rises in weights are partly due to foraging on ivy and partly to feeding. Thereafter, the average weight loss over winter for all colonies was 5.8 kg (12.7 pounds). The average weight loss rates in all four winters were 0.031, 0.034, 0.030 and 0.052 kg/day. Average October-March temperatures for those winters at a distance of 250 metres from the hives were 8.9, 8.3, 9.8 and 9.4°C and the overall range of monthly averages was 6.4-14.4°C.

John Humphreys of Conwy (Wales) Beekeepers Association reports graphically at http://www.conwybeekeepers.org.uk/new-beekeepers/measuring-beehive-stores-in-winter/ weight changes for three hives from October to March. Interpolating from his graph, the drop in weight over the period 19 October to 10 March (146 days) was 11.6 kg. This represents a rate of fall of 0.079 kg/day. No temperature data are given but as Conwy is only 64 km from David Heaf's apiary (data reported immediately above), it should also have a similarly relatively mild winter climate.

In Germany there are scores of hives on scales with their continuously monitored data being uploaded to the Internet. The system is called 'Trachtnet' and offers a clickable map at http://www.bienenkunde.rlp.de/Internet/global/inetcntr.nsf/dlr_web_full.xsp?src=7DE6581RTC&p1=510TV6HBBL&p3=5PW3P32TF7&p4=HY3576SY58. Six sites were chosen, the choice depending on monitoring data for a reasonably long period of winter (2016-2017) and no serious interruptions or anomalies in the data charts. For example, it appears that some hives gain weight due to snowfall. The following table summarises the falls in weight for the six chosen sites.

Site	**Start date**	**Finish date**	**Start weight**	**Finish weight**	**Days**	**Weight loss**	**kg/day**
Lübeck	7 Oct	24 Mar	45.2	36.8	168	8.4	0.050
Bautzen	17 Oct	24 Feb	59.4	48.1	130	11.3	0.087
Aichach-Friedberg	7 Nov	2 Apr	64.5	55.4	146	9.1	0.062
Eichsfeld	26 Oct	25 Mar	35.5	29.1	150	6.4	0.043
Saarbrücken	20 Nov	8 Feb	53.9	48.8	79	5.1	0.065
Heinsberg	7 Oct	13 Mar	59.7	48.2	157	11.5	0.073
						Average	**0.063**

Alexander Wilms, a beekeeper in Nettetal, North Rhine-Westphalia, Germany includes ambient and in-hive temperatures with his live hive weight data for 2015-2017 at https://www.imker-nettetal.de/bienen-nsa/. In the 2016-2017 winter between 4 October and 1 April his hive (type: Zander) lost 15.6 kg and the following winter, between 1 October and 11 March, 13.4 kg. The daily loss rates were 0.088 kg/day and 0.083 kg/day. The average temperatures of the two 6-month winter periods were 8.0°C and 7.3°C and the overall range -3 to +18°C.

Also in Germany there is the long-running HOBOS project monitoring many parameters associated with beehives. A scrollable visualisation dashboard for three hives is accessible at https://grafana.biozentrum.uni-wuerzburg.de/dashboard/db/weight-of-all-hives.

Site	**Start date**	**Finish date**	**Start weight**	**Finish weight**	**Days**	**Weight loss**	**kg/day**
Würzburg	9.10.13	29.3.14	59	53	171	6	0.035
Würzburg	22.10.14	1.4.15	59	51	160	8	0.050
Bad Schwartau	22.10.14	1.4.15	53	45	159	8	0.050
Bad Schwartau	7.10.15	31.3.16	57	48	165	9	0.051
Würzburg	7.10.16	14.3.17	55	49	158	6	0.038
Bad Schwartau	7.10.16	14.3.17	55	47	158	8	0.051
Münchsmunster	7.10.16	14.3.17	15	5	158	10	0.063
						Average	**0.048**

Jean-Luc Strebelle (Belgium) reported a hive weight loss of 6.7 kg from 1 October 2009 to 15 February 2010 (138 days) indicating a loss rate of 0.049 kg/day. http://www.apiculture-wallonie.be/sites/default/files/Suivi%20de%20la%20miell%C3%A9e%20gr%C3%A2ce%20%C3%A0%20la%20pes%C3%A9e.pdf

A resource also in Belgium presented at http://www.cari.be/balances/ shows online weight and temperature data for 16 hives in the Wallonia/Brussels region. Data for the 2016-2017 winter were examined. Several data sets have inexplicable drops or peaks during the winter period and were ignored. Four sets of satisfactory length are presented here with average October-March temperatures. The overall temperature range was -5 to 17°C.

Site	**Start date**	**Finish date**	**Start weight**	**Finish weight**	**Days**	**Weight loss**	**kg/day**	**Average Temp. °C**
Beauraing	4.10.16	13.3.17	56.6	50.9	160	6.7	0.041	5.3
Brussels Uccle	4.10.16	14.3.17	44.7	35.7	161	9.0	0.056	6.6
Jandrain	4.10.16	22.3.17	45.0	35.6	169	9.4	0.056	6.0
Liège Centre	8.10.16	2.3.17	56.6	49.6	145	7.0	0.048	7.2
						Average	**0.050**	

Data from an unidentified beekeeper in SE France are posted at http://mesruches.shost.ca/ under the heading 'Rucher du Château'. Photos show the apiary covered with snow. At http://www.apiculture-france.com/t13349-projet-de-balance-electronique the beekeeper posts as 'GPA' and identifies his location by the postcode 38590. It was possible to extract pre- and post-winter data for three hives.

Hive	**Start date**	**Finish date**	**Start weight**	**Finish weight**	**Days**	**Weight loss**	**kg/day**
14	13.10.16	29.3.17	39.1	29.0	167	10.1	0.060
8	13.10.16	1.3.17	38.9	28.8	139	10.1	0.073
7	13.10.16	28.3.17	40.6	27.7	168	12.9	0.077
						Average	**0.070**

A graph at http://mesruches.shost.ca/Tracer_Dygraph1.php?page=25 shows October to the April temperature range as -6°C to +15°C. No raw data are available for calculating the 6-monthly average.

The potentially rich resource for hive weight data is hivetool.org with hive data presented at hivetool.net which, at the time of writing, showed 32 hives reporting data within the previous 15 minutes and many more hives indicated as having recorded data earlier. Furthermore, it offers satisfactory visualisation of data and CSV download of data values. However, the site was very unresponsive at the time it was examined and many of the hives had no winter weight data or the values were very erratic. Most of its hives are in the USA. After many attempts to access data for the various hives, only two gave meaningful winter data. The hive identified as Doppelbienen Redwood City (California) weighed 30.3 kg on 10 December 2016 and 21.3 kg on 24 March 2017. In the 104 days it lost 9 kg, representing a rate of 0.087 kg/day. The average temperature during the period was 13°C. The hive at Lillesand, Norway weighed 19.1 kg on 30 September 2016 and 14.7 kg on 22 January 2017. In the 114 days it lost 4.4 kg, representing a rate of 0.039 kg/day. The average temperature was 3.9°C.

Data from a personal communication

Andy Collins (Perthshire, Scotland) has supplied data for 6 colonies over two winters in modified Warré hives with unusually thick walls. The results are shown in the table on the following page. Collins warns that the method of measurement risks an estimated random error of up to 0.8 kg. However, we shal assume here that this error all or partly cancels out in the data set presented immediately below.

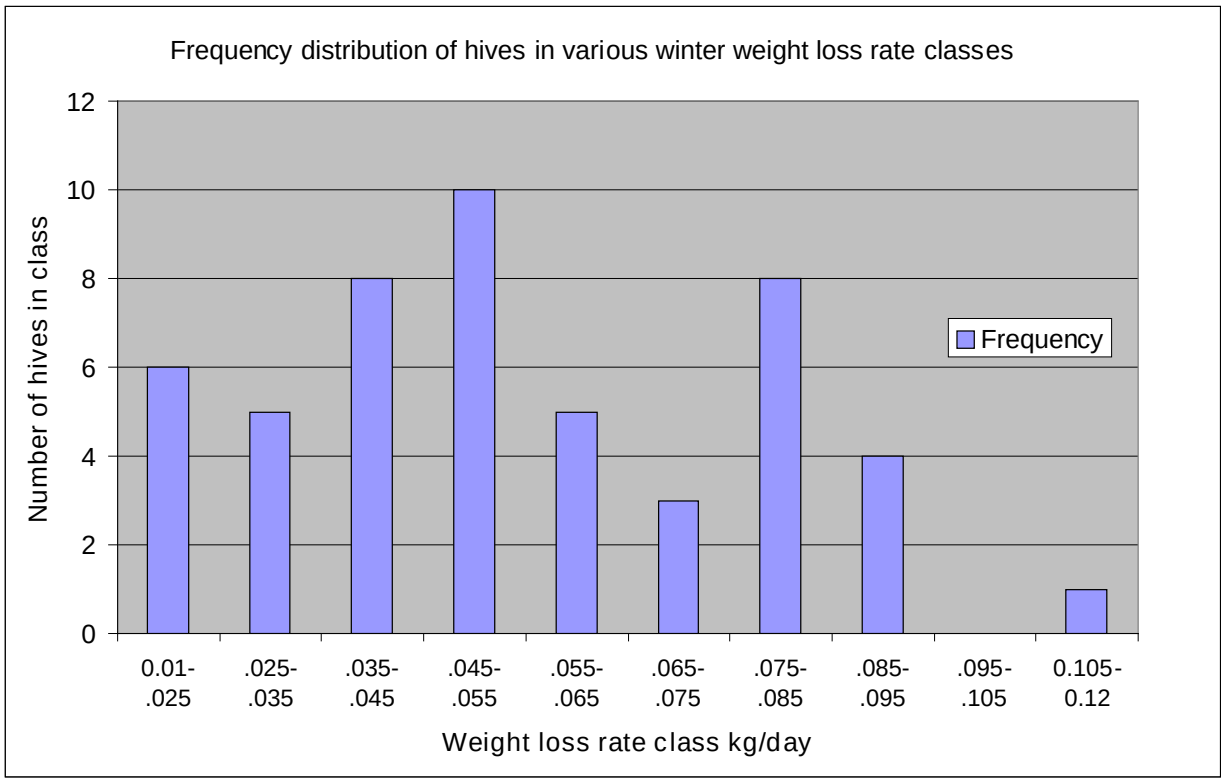
Colony	Start Date	End Date	Mass Difference (kg)	Days	Kg/day
E2	12/10/12	15/3/13	2.0	154	0.013
H1	3/10/12	14/3/13	3.4	162	0.021
H2	3/10/12	14/3/13	4.6	162	0.028
T3	15/10/14	1/4/15	4.7	167	0.028
M1	16/9/14	2/415	2.7	167	0.016
M2	2/11/14	1/4/15	3.1	150	0.021
				Average	**0.021**

The striking thing about these data is that they are all below values found in the rest of this survey. We can speculate on the possible causes of this. That the box walls were unusually thick (either 30 or 50 mm) compared with most modern hives, seems a prime candidate as the greater insulation involved could have reduced stores consumption. Other possibilities suggested by Collins are the colonies comprising a high local percentage of *Apis mellifera mellifera*, a race known to be comparatively frugal; the total lack of disturbance of the colonies; the fully continuous and completely freestyle combs some of which extend through several boxes as the central top-bars are removed; and/or quite small winter clusters.

Results summary and discussion

Of the 51 hives reported in this survey the lowest weight loss rate was 0.013 kg/day for colonies in Perthshire (Scotland) and the highest 0.118 kg/day for bees of unspecified race near Montpellier, France (Meikle et al. 2008). These two sites represent climate extremes, the former northern and coold, and the latter southern and warm. This accords with common observations that colonies at ambient temperatures warm enough to make them active in winter consume more stores. The two contrasting hives in California and Norway, whose data from hivetool.net are shown in the immediate paragraph, illustrate the same point.

The results from the entire survey were plotted in a frequency distribution histogram as shown in the following chart.



The frequency distribution was bimodal,, the reason for which is unknown. Given the wide variety of factors influencing consumption of winter stores, it seems probable that a larger data set from a broad range of climates would have produced a flatter or more rounded distribution.

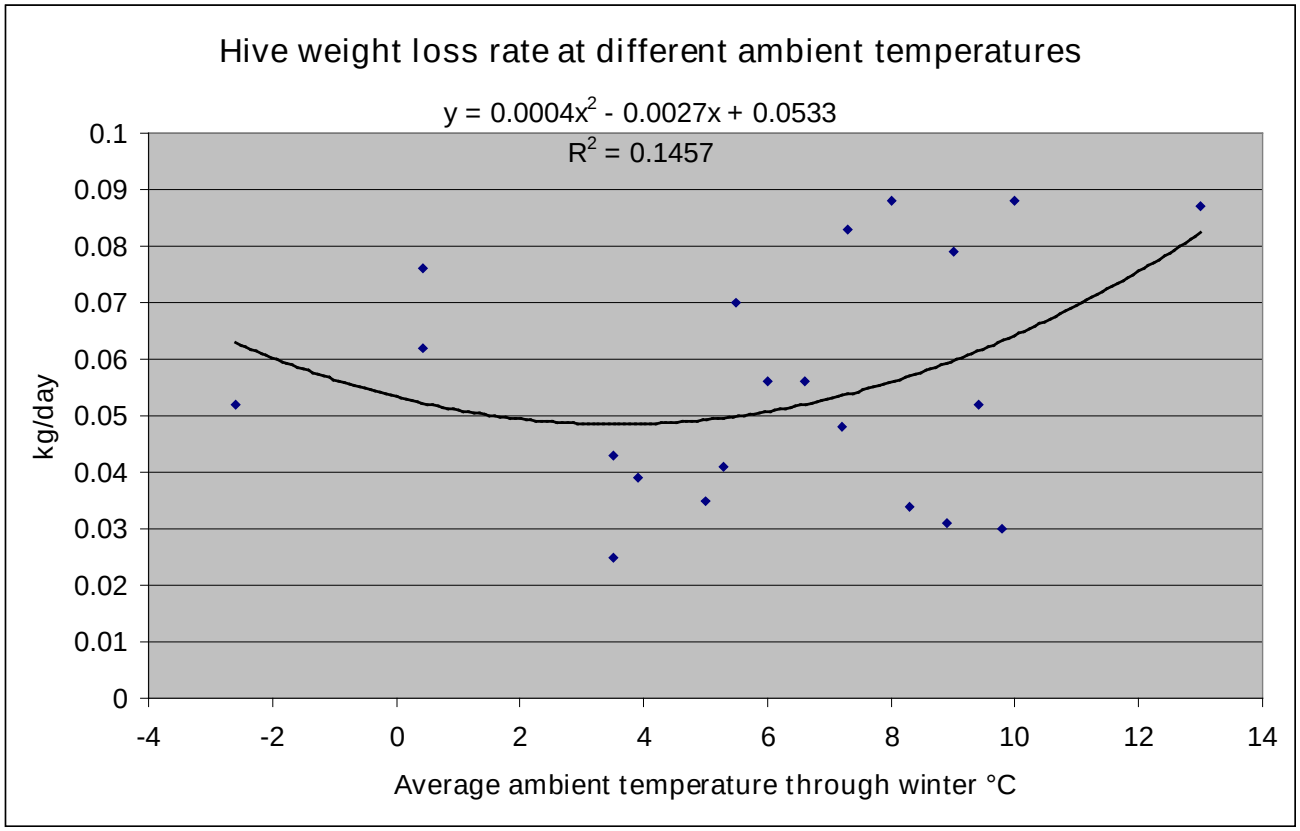
Given the bimodality of the distribution, not much significance can be attached to the fact that the average weight loss rate for the 51 hives was 0.54 kg/day. For a winter period of 1 October to 1 April, if the weight loss is entirely made up by loss in weight of honey stores, this is equivalent to a consumption of stores of 9.8 kg. This is well within the figure of 12 kg that Warré (1948), who was based in northern France, advised as the stores weight necessary for successfully wintering his 'Peoples Hive'.

It should be mentioned that not all the weight loss of a winter colony is due to stores consumption. Figure 11.1 in Winston (1987) would indicate that about between 1 October and mid-February about 9,000 bees die. At 90 mg per bee this would account for about 0.8 kg of the winter weight loss, or about 7.5% based on the average. Avitabile (1978) also reports a loss of 9,000 bees through the winter (November to March).

A striking feature of almost all the data sets resulting from continuous monitoring is their linearity, i.e. the weights show a gradual decrease in a straight line despite the fact that the temperature may go through a cycle of some twenty degrees during the winter. We may speculate that any decrease in honey consumption by the bees due to lower heat loss at the higher ambient temperatures may be offset by the increased activity of the bees at those temperatures.

The highest consumption rate found, 0.118 kg/day, an obvious outlier on the above histogram, equates to a 1 October to 1 April winter consumption of 21.5 kg. As regards the risk of starvation, this figure makes the figure of 25 kg stores recommended by the UK National Bee Unit (http://www.nationalbeeunit.com/public/News/news.cfm#190) seem extraordinarily, if not excessively, safe.

With the average winter temperature values available for 21 of the data sets it seemed worthwhile to look at how weight loss rate changes with temperature. The results are shown in the following figure. As it is known that a colony's consumption of honey reaches a minimum at about 5°C and rises either side of that temperature, a polynomial, in this case a parabola was fitted to the data points.



The data are clearly a poor fit to the model though it places the vertex, the minimum value of weight loss, at 3.4°C.

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