HOW DOES SOLAR OVEN PERFORMANCE VARY WITH THE SEASONS?

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Abstract

I built a solar oven. I tested it in spring, summer, fall, and winter. I cooked bread, an egg, and mini blueberry muffins. The egg cooked all year, the bread and muffins cooked all year except in the winter.

Purpose

To see how solar oven performance varies with the seasons.

Background information

Horase de Saussure, a Swiss naturalist, built the first solar oven in 1767. His oven reached a maximum temperature of 190° Fahrenheit and he used it to cook fruits. And he is considered the grandfather of solar cooking.

There are other reports in history of people using solar ovens to cook food. In 1877, August Mouchot, a French scientist, designed and built solar cookers for French soldiers in Africa to use. Later in India, a British soldier patented a solar oven with reflectors. A Chinese restaurant in 1894 served solar cooked food. An early sea captain created a solar oven he could use on long voyages. The first modern solar cooker was invented by William J. Bailey in California in 1909. Solar ovens have been becoming more popular since the 1950's. The United Nations has been studying the usefulness of solar ovens in poor countries.

A solar oven like I made is based on the greenhouse effect. According to Stanford University there are three main principles involved in solar cooking.

- "Directing the greatest possible amount of the sun's light to the food by means of reflection." I did this in my oven by a reflector made of cardboard and aluminum foil. and a shiny foil interior.
- "Converting these light waves into heat energy." And I did this by my black cardboard absorber and my black frying pan for the egg.
- "Effectively retaining heat energy by insulating the cooker." I did that by insulating it with Styrofoam covered in aluminum foil. and using double pane glass sealed with silicone.

A flat plate collector with no reflectors can reach 300° F (see figure 1). If you add reflectors to collect more sunlight the oven can sometimes reach 350°F or 400° F.

With food inside the oven won't get as hot because the food absorbs a lot of the heat.

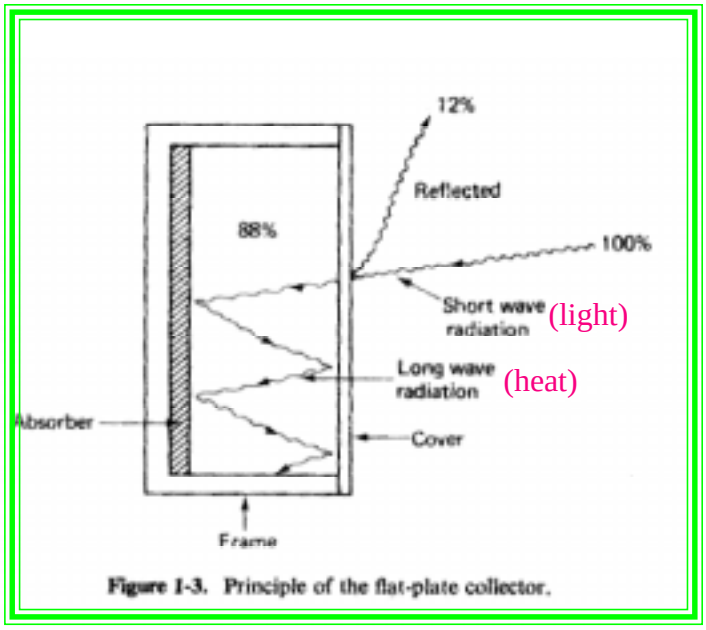

Figure 1-3. Principle of the flat-plate collector.

Figure 1

Solar ovens are very useful in poor and tropical countries where they don't have enough trees to

cook everyone's food. Nearly 50% of the rainforests that are being cut down are being used for firewood to cook food. A forest area the size of Wisconsin is burned in Africa every year. If solar ovens were used a lot there would not be so many wood shortages around the world. The United Nations and other groups have been trying to introduce solar ovens in these poor countries. however, many people are not willing to change tradition and try something new. Here are some of some reasons they give for not using solar cookers: they cook slowly and they're different from what people are used to. you can't cook when it's cloudy. and they blow over in the wind. One time the United Nations gave 500 wooden solar cookers to a refugee camp and 3 months later they were chopped up and used for firewood. But in other countries where there is no firewood people are more willing to use them. In northern Mexico the UN gave some people some cookers and they were still being used 5 years later. Tibet is becoming the first solar cooking country in the world because it is above tree line so there is no firewood and it's high in the mountains where there's lots of sunshine.

In addition to saving trees if people in tropical countries used solar ovens to heat their water before they used it. they would not get sick as often. because it would kill the germs that spread terrible diseases such as cholera.

The reason I picked this project is because I wanted to know if a solar oven would work this far north. and also Colorado has lots of sunshine and mountains just like Tibet (see figure 2).

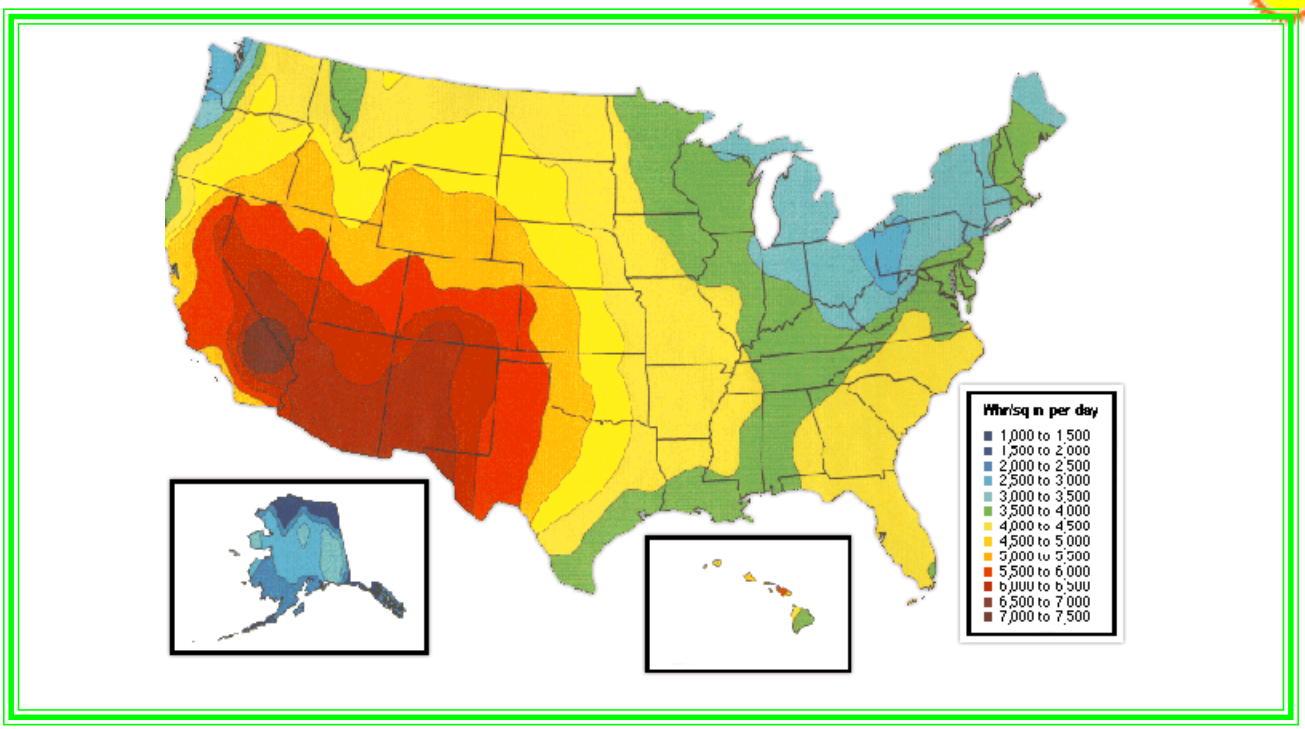

Figure 2 Solar radiation map of the US

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Hypothesis

I think that the bread will only cook in the summer. same with the muffins. But the egg will cook all year long. And I think that the egg will take longer to cook in the winter.

Materials

Oven

- Styrofoam 1 inch thick
- cardboard box 11 x 17 x 12 inches with lid
- aluminum foil
- rubber cement tape
- black spray paint
- 1 plexiglass panel
- 1 glass panel
- 2 hinges
- silicone sealant
- 1 cake cooling rack
- oven thermometer
- one piece of cardboard
- one piece of foam board

Figure 3 Cutting the styrofoam

Figure 4 Painting the oven

- an extra box lid
- Elmer's glue
- hot glue

Figure 5 Bread

Food

- egg + black frying pan
- bread dough + mini bread tin
- muffin mix + mini muffin tin

Figure 6 Cooked egg

Procedures

Building the oven

1. I spray painted the box black and cut a hole in the top for the glass.
2. I covered the Styrofoam with aluminum foil.
3. I used Elmer's glue to glue the Styrofoam into the box.
4. I glued the plexiglass into the box lid.
5. I put spacers inside on the plexiglass.
6. I glued the glass inside the plexiglass and sealed the crack with silicone.
7. I glued the oven inside the extra box lid to tilt it 15° toward the sun.
8. I glued the cut out from the lid to the inside back surface of the oven for an absorber.
9. I glued the foil to the cardboard reflector, and glued the foam board to the

back of the reflector.

10. I attached the reflector to the oven with the hinges.

11. I put the oven rack into the oven so that it was horizontal so the food would be horizontal and so that it was also up off the floor of the oven.

12. I put the oven thermometer in the oven.

Running the Experiments

I did the following procedures for an egg, mini muffins, and a small loaf of bread. I ran the experiment in spring, summer, fall, and the winter.

1. I put the food in the oven.

2. I put the oven in the sun so that its shadow was straight behind it and adjusted the reflector so that it was shining in the oven.

3. Every 20-40 minutes I took a reading of the oven temperature, the outside temperature, cook time and how the food looked.

4. I adjusted the positions of the reflector and oven if necessary.

5. When the food looked done I took it out of the oven.

Figure 7 Bread cooking in the oven

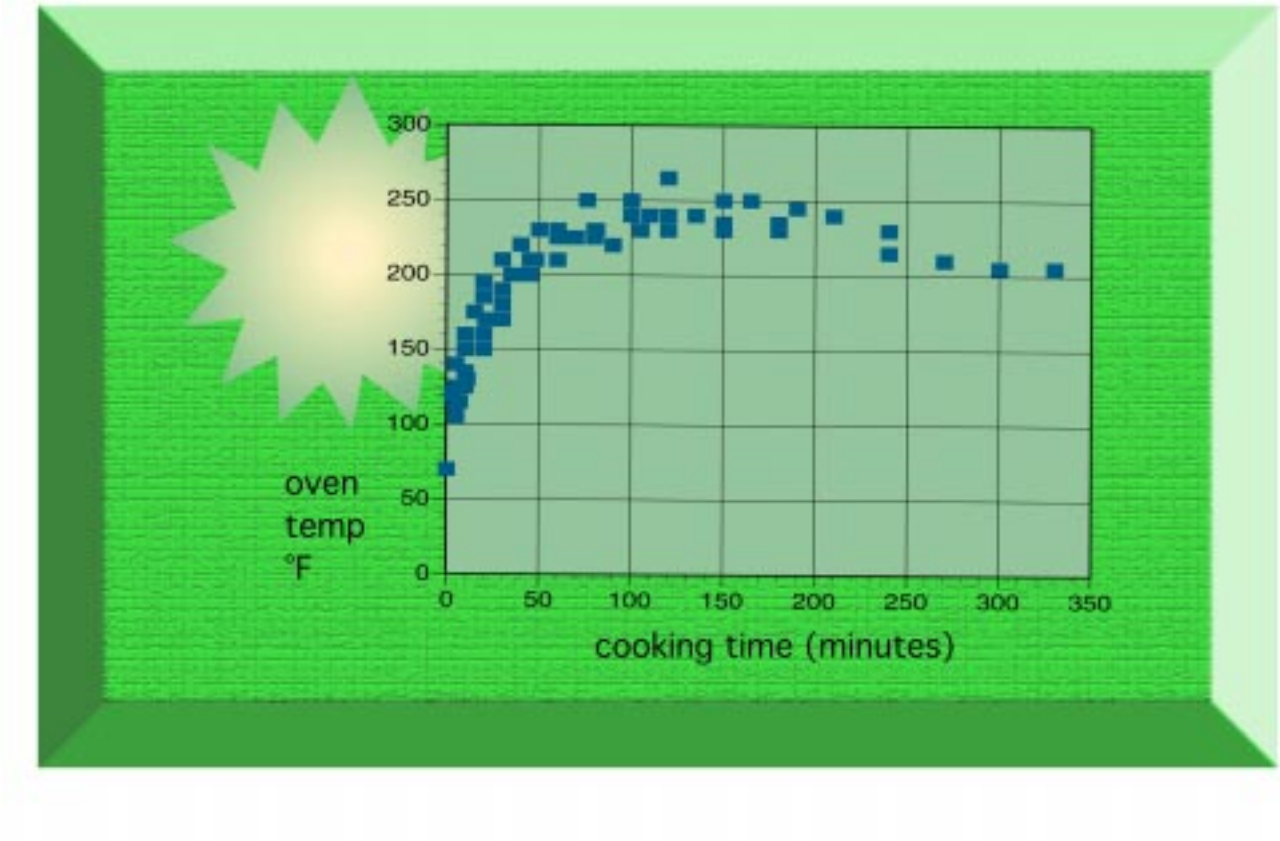


Figure 8. Oven temperatures in the spring.

Results

The egg cooked all year long but it took longer in the winter. And the bread cooked all year except in the winter. The maximum oven temperature in the spring was 250° F (see Figure 8). The maximum oven temperature in the summer was 230° F (see Figure 9). The maximum oven temperature in the fall was 230° F (see Figure 10). The maximum oven temperature in the winter was 160° F(see figure 11). I expected the oven to get hotter in the summer than in any other season. But it didn't—my results showed that it got hotter in the spring (see Figure 12).

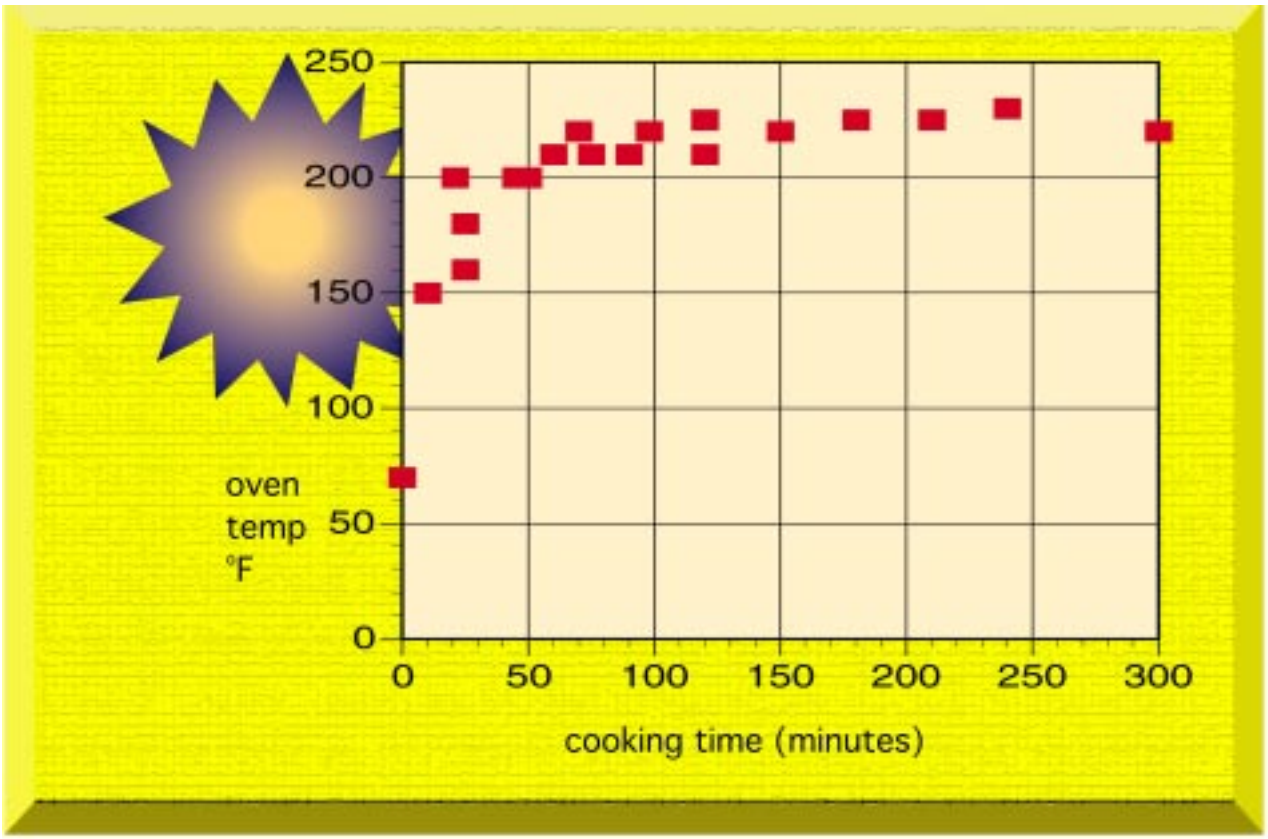


Figure 9. Oven temperatures in the summer.

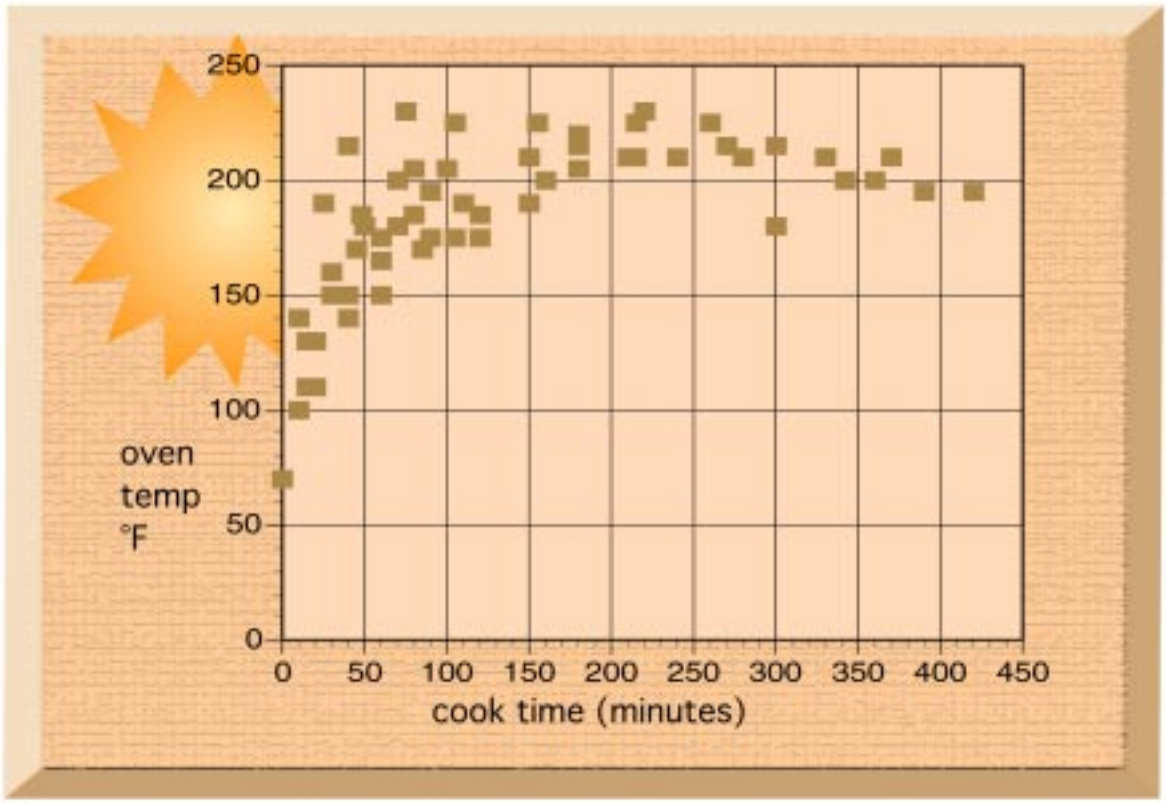


Figure 10. Oven temperatures in the fall.

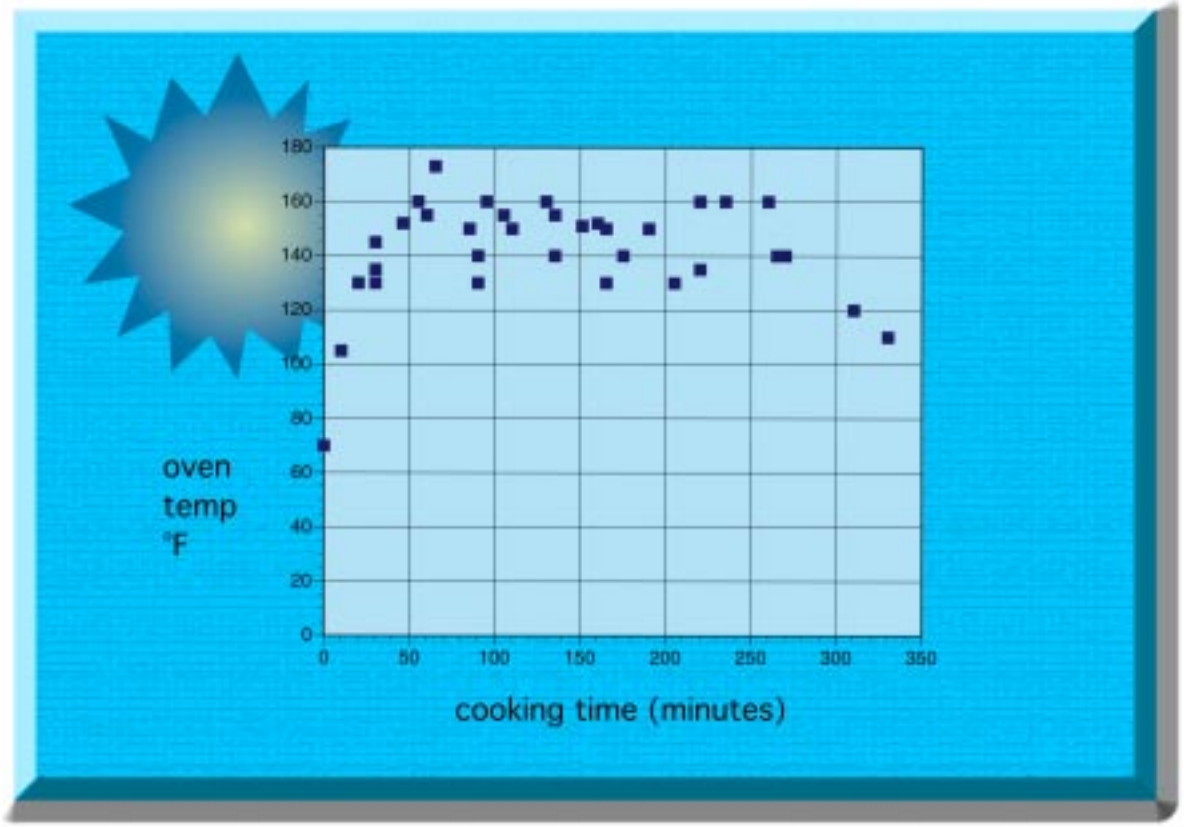


Figure 11. Oven temperatures in the winter.

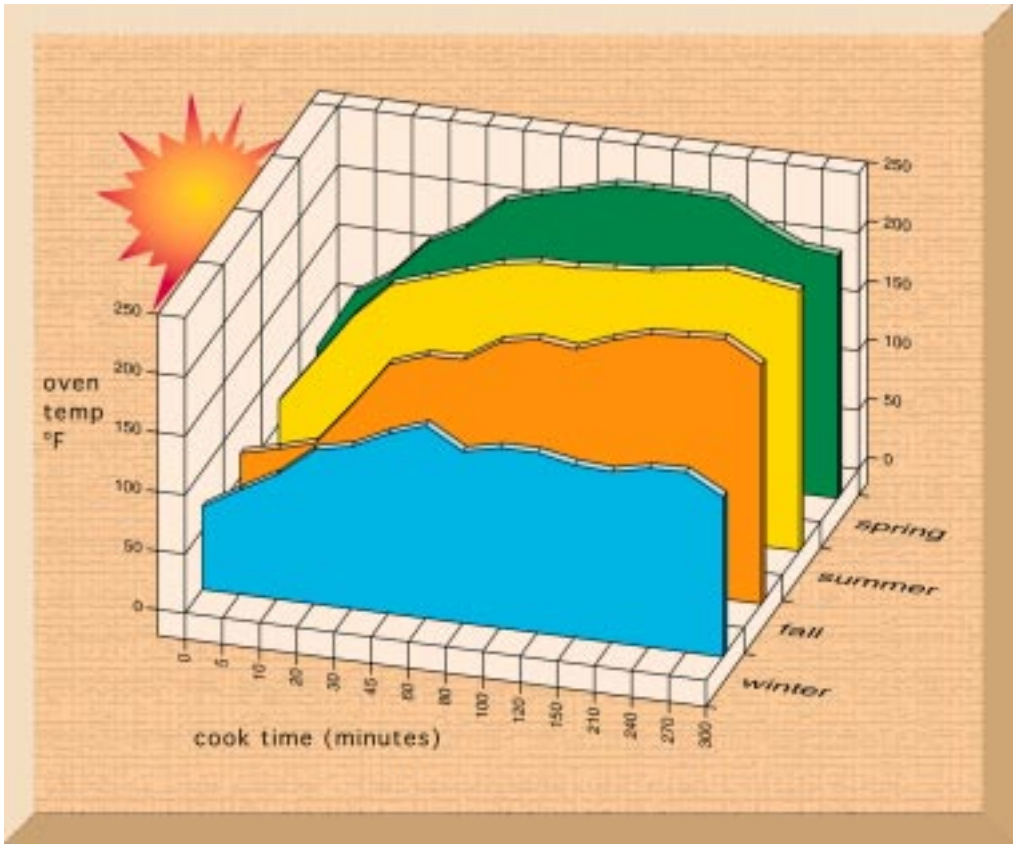


Figure 12. Temperature profiles in the different seasons .

Why would this be? I can answer the question of why it did not get hotter in the summer. I took my data late in the summer, not near the summer solstice, because I was on vacation then. The amount of sunlight collected in the summer was about the same as in the spring (see appendix A). But why it did not get as hot in the summer as in the spring I do not know. My grampa suggested that maybe there was more humidity in the air in the summer, and my books said that a solar oven will not get as hot when there is a lot of humidity because the humidity absorbs some of the sunlight even though it is very hard for a person to see. Also I made a graph to see if there was a relationship between the outside temperature and the oven temperature, and there wasn't (see Figure 13). That shows that only the amount of sunlight matters—my oven was well insulated.

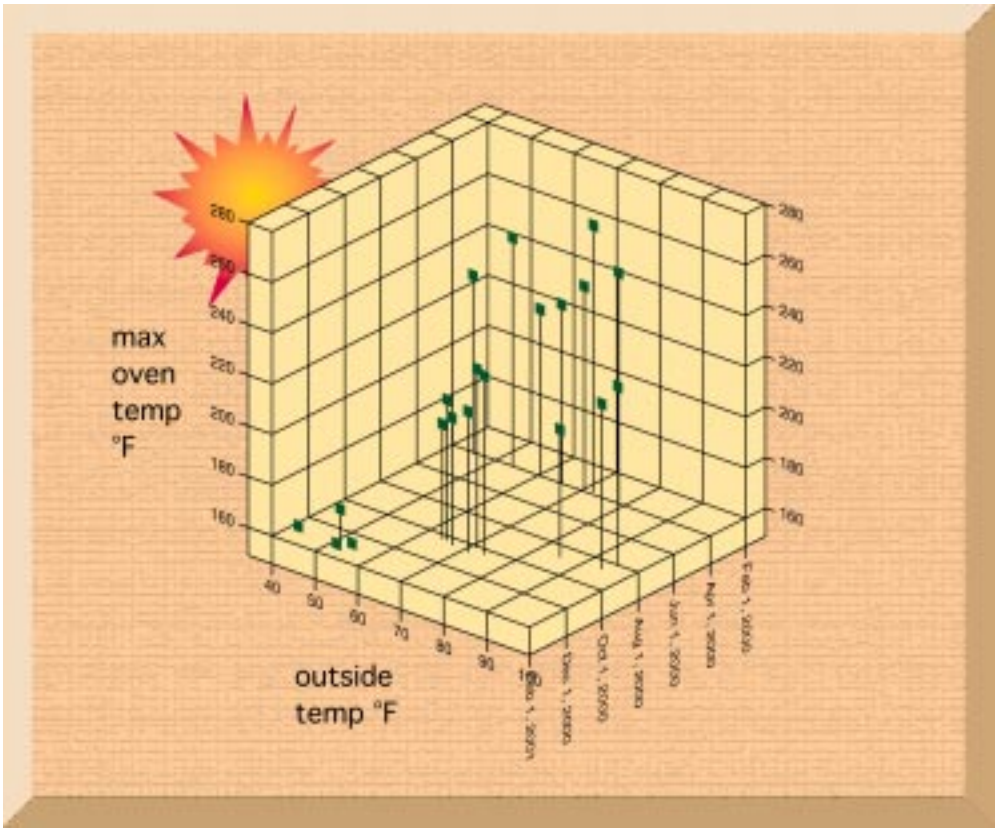


Figure 13. Maximum oven temperature vs. outside temperature. The outside temp does not look like it matters to the oven temp because the points are all scattered. And the oven got hotter in the spring when it was 40° than when it was 40° in the winter.

Conclusions

My hypothesis was only partially correct. The egg cooked all year as I expected. The bread and the muffins cooked all year except in the winter which was better than I expected. And it did take the egg longer to cook in the winter (see Figure 14).

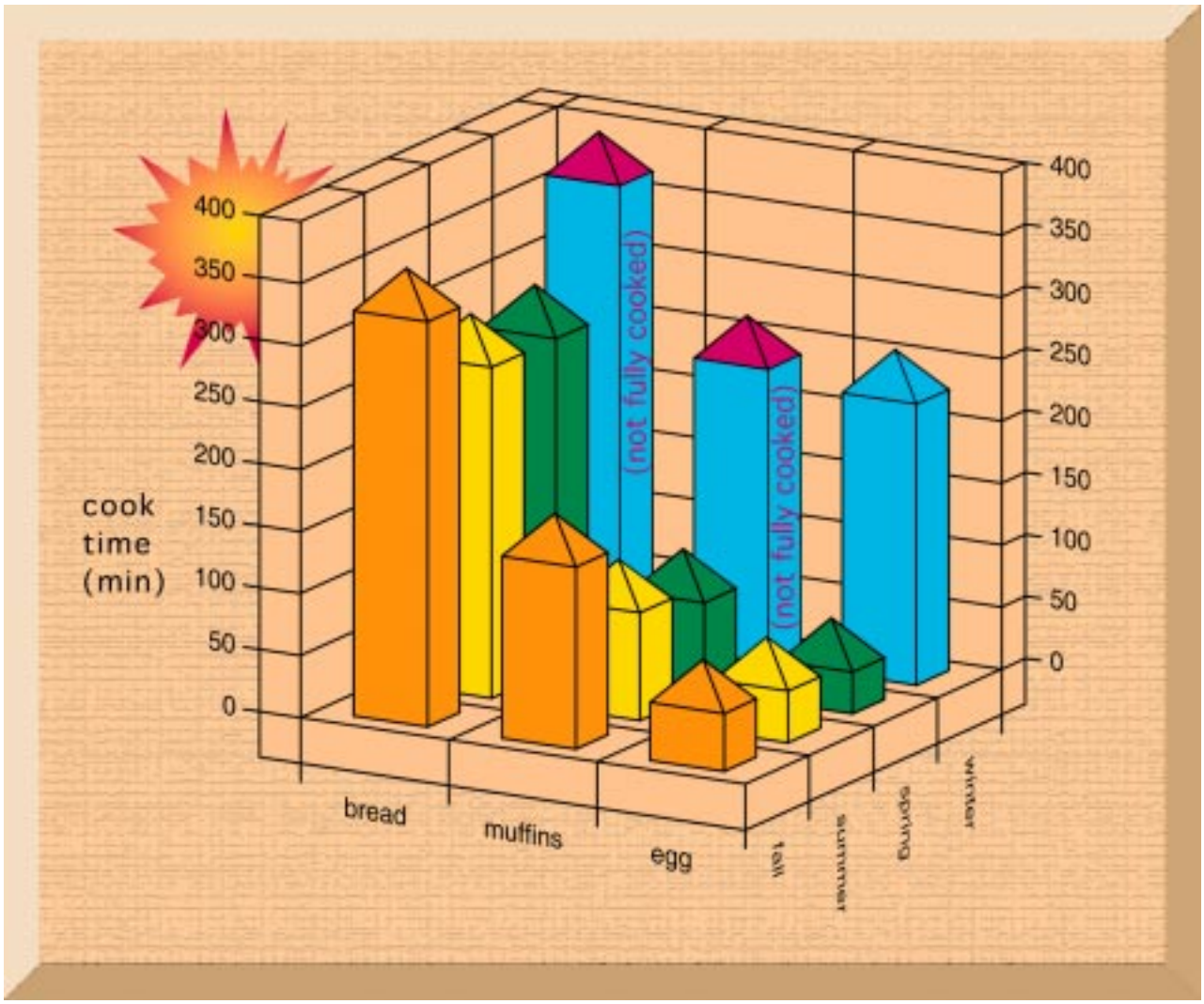


Figure 14. Cooking times for the foods in the different seasons. In the winter the bread and the muffins only partly cooked on the top but were still mushy on the bottom.

Acknowledgements

1. Thank you to my mama and Mattie (my sister) for helping me build the oven and take readings.

2. Thank you to my Grampa for suggesting the reflector.

3. Thank you to my Gramma for telling me about the mini bread pans at Safeway.

4. Thank you to me, my sister, my mama, my Gramma, Grampa, my daddy and my dog Moe for eating the food.

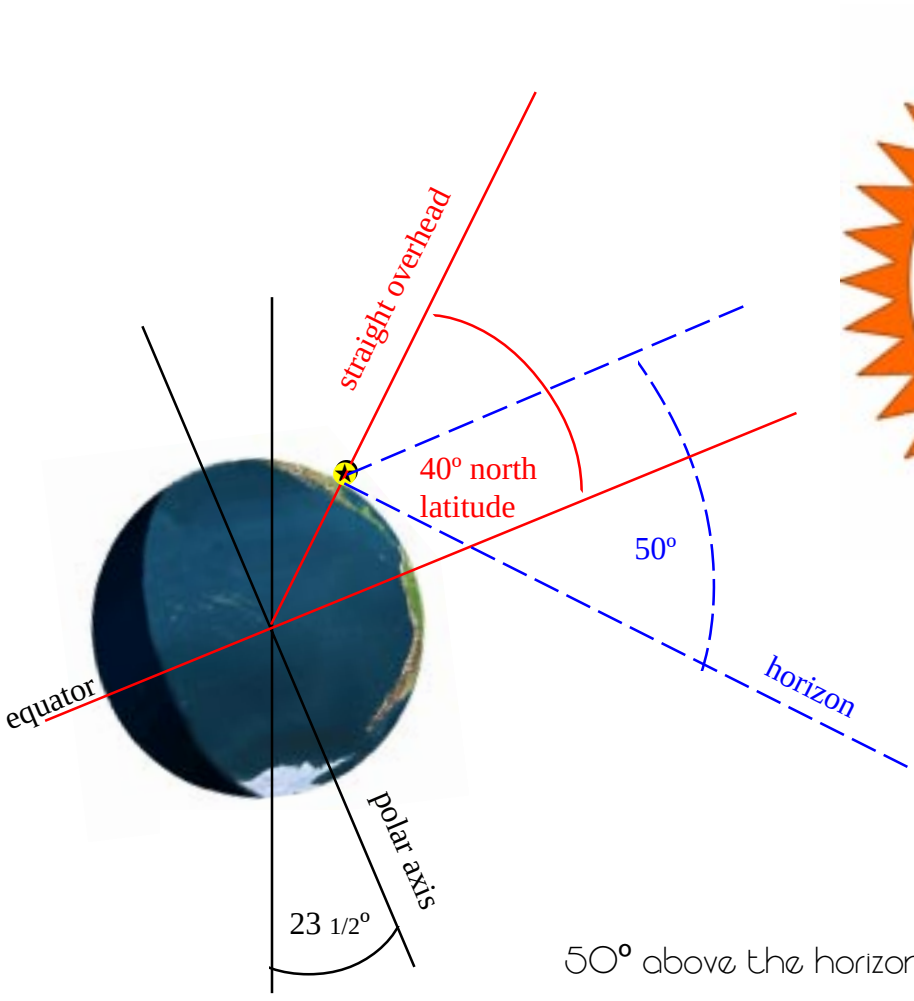
5. Thank you to my mama for showing me how to use DeltaGraph, Illustrator, Typestyler, PhotoShop, and Pagemaker so that I could write up my report.

Appendix A

Solar Angle and Collection of Sunlight

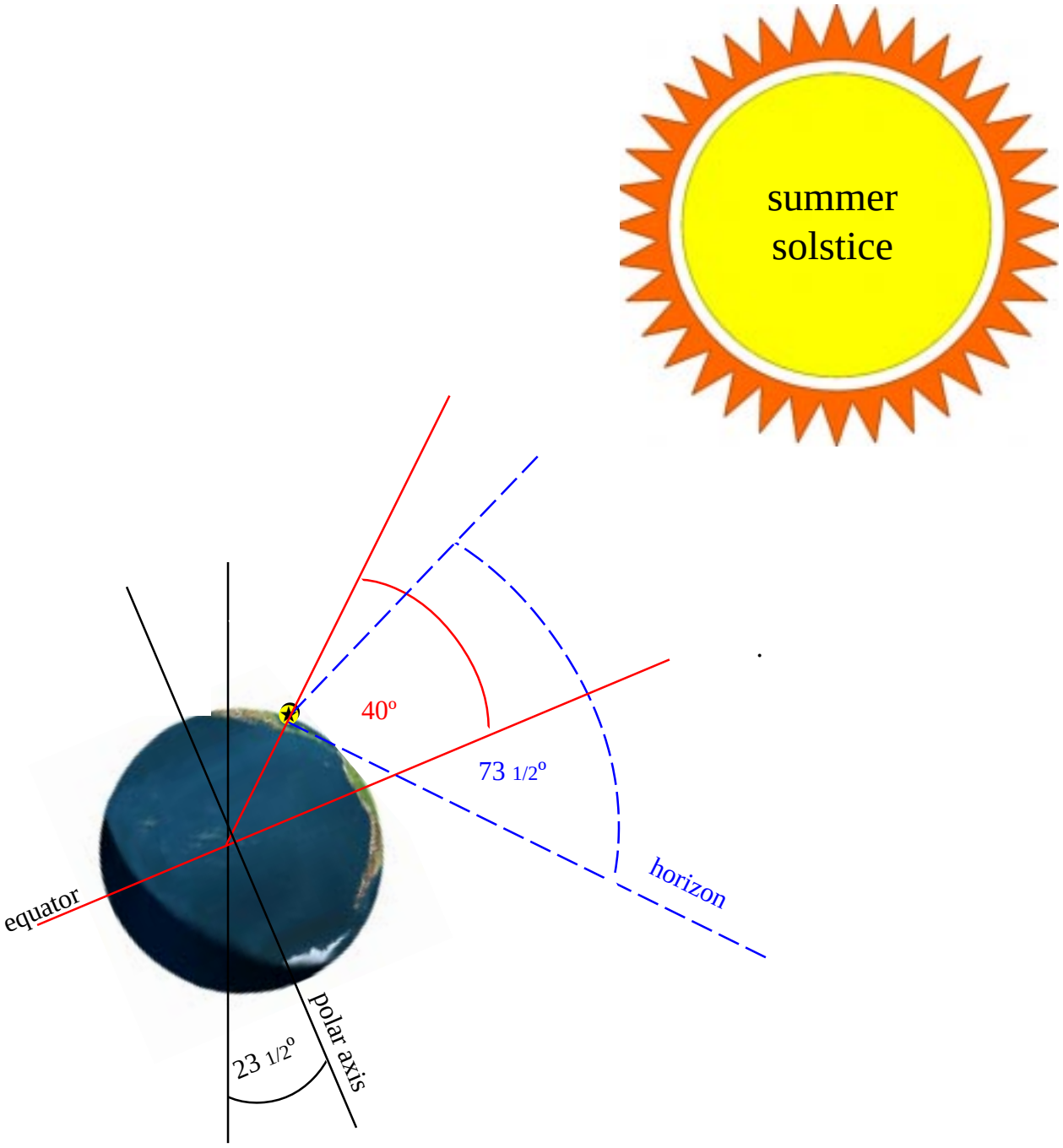
The earth's axis (north and south poles) is tilted at 23 1/2° from a line perpendicular to the earth's orbit. This is why we have seasons, because the maximum angle the sun reaches above the horizon changes at different times of the year.

We are at 40° north latitude. At the spring and fall equinoxes, the sun is directly overhead at noon at the equator. The sun reaches a maximum angle of

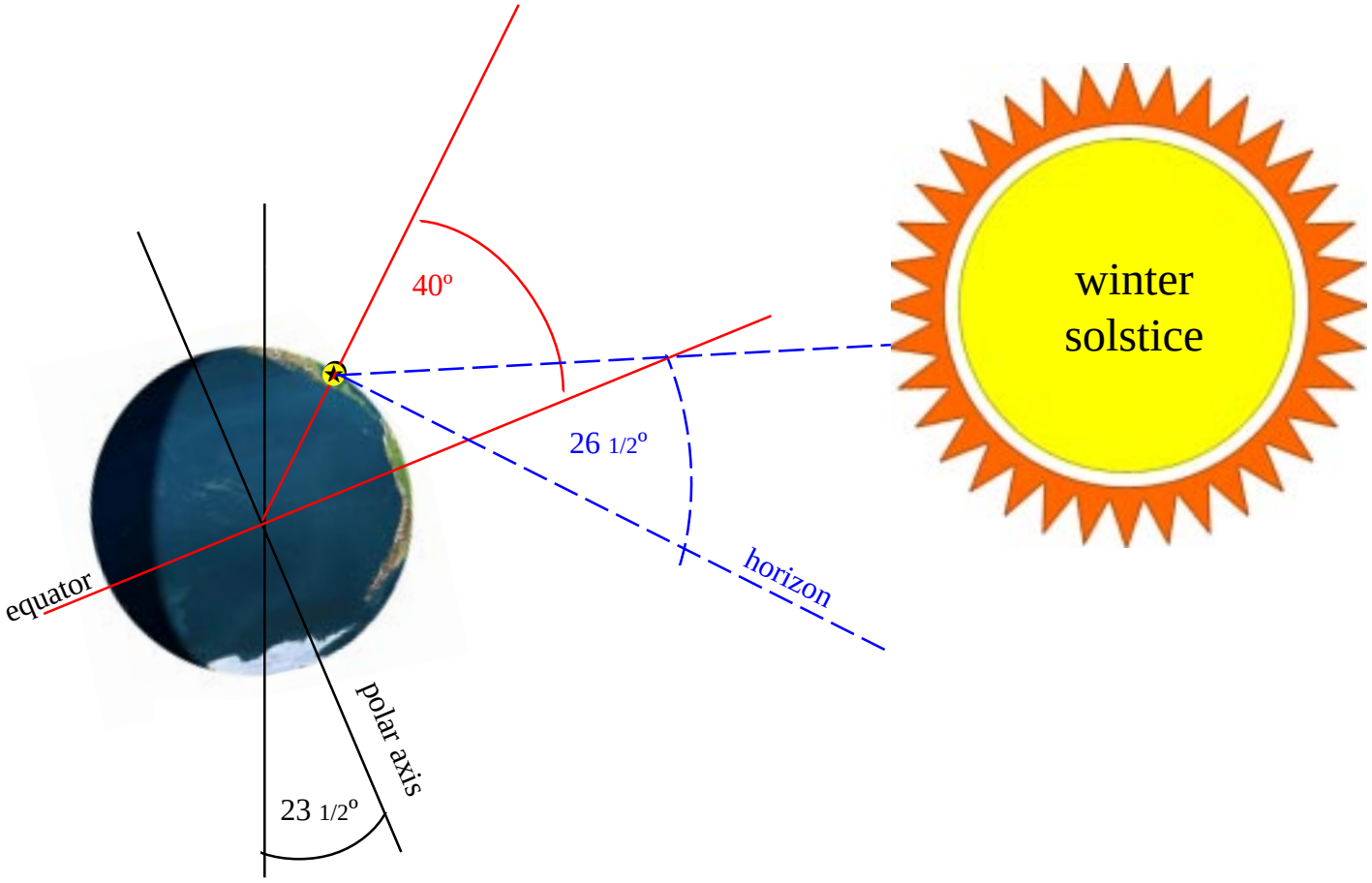


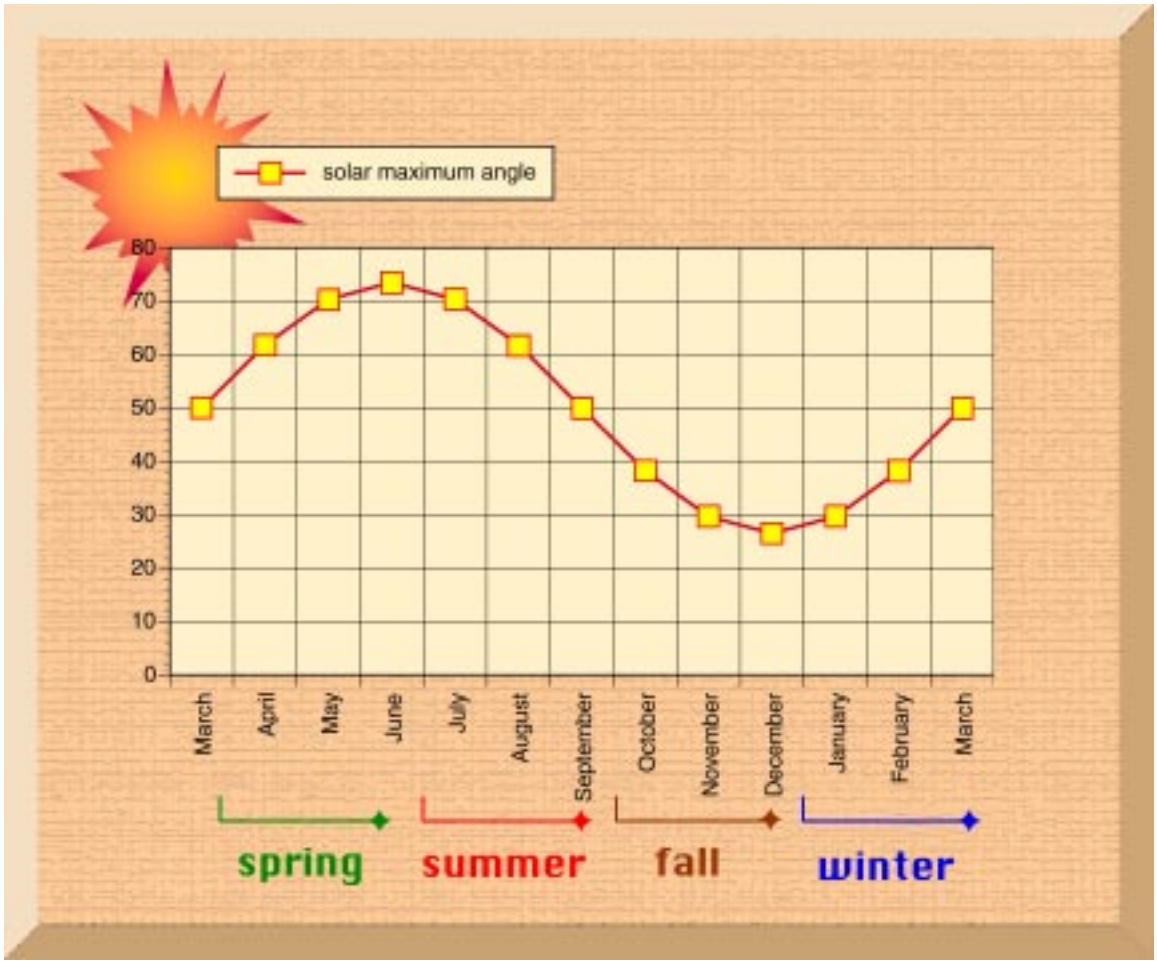
50° above the horizon here on the first day of spring and the first day of fall.

The sun is highest in the sky at noon on the summer solstice (first day of summer), so this is when the solar oven collects the most sunlight. At the summer solstice, the sun is overhead at noon 23 1/2° above the equator, at the Tropic of Cancer. Here it is 50 + 23 1/2 = 73 1/2° above the horizon at noon



On the first day of winter, the highest angle the sun reaches here is only 26 1/2° above the horizon, because at the winter solstice, the sun is 23 1/2° below the equator at noon (overhead at the Tropic of Capricorn), so it is 50 - 23 1/2 = 26 1/2° above the horizon for us at noon.





This graph shows how high the sun gets in the sky at the different times in the year. In August and April the sun is at the same place in the sky (about 60°) when I took my readings in the summer and the spring. This explains why the oven did not get hotter in the summer than in the spring.

I built a model of the angle of the sun's rays that shows the directness of the sun's rays in the different seasons to go with my exhibit.

Appendix B

Data

3/26/2000	time	outside temp °F	oven temp °F	cook time min	food looks like
egg	09:42 AM	62	under 100	0	raw
	09:45 AM	62	120	3	“
	09:47 AM	63	140	5	“
	09:52 AM	63	160	10	“
	09:57 AM	64	175	15	starting
	10:02 AM	66	185	20	to cook
	10:12 AM	69	210	30	white cooking
	10:30 AM	69	210	48	“
	10:42 AM	70	230	60	“
	10:58 AM	68	250	76	“
	11:22 AM	72	250	100	white drying up
	11:42 AM	72	265	120	“
	12:32 PM	68	140 (clouded over)	170	yolk cooked (overcooked)

3/27/2000	time	outside temp °F	oven temp °F	cook time min	food looks like
muffins	09:00 AM	60	under 100	0	raw
	09:05 AM	60	110	5	“
	09:10 AM	62	135	10	starting to rise
	09:20 AM	62	160	20	“
	09:30 AM	63	190	30	cooking
	09:36 AM	63	200	36	“
	09:45 AM	64	210	45	“
	10:00 AM	66	225	60	edges puffier
	10:20 AM	68	230	80	than middles
	10:41 AM	70	240	101	starting
	11:00 AM	71	240	120	to brown
	11:30 AM	72	235	150	done (overcooked)

3/29/2000	time	outside temp °F	oven temp °F	cook time min	food looks like
egg	09:03 AM	55	under 100	0	raw
	09:10 AM	55	115	7	“
	09:24 AM	55	170	21	“
	09:38 AM	56	200	35	cooking
	09:50 AM	56	210	46	“
	10:10 AM	60	225	67	done (soft cooked)

3/29/2000	time	outside temp °F	oven temp °F	cook time min	food looks like
muffins	10:30 AM	63	under 100	0	raw
	10:35 AM	63	125	5	starting
	10:50 AM	64	185	20	to rise
	11:10 AM	64	220	40	puffy
	11:30 AM	64	225	60	cooking
	11:50 AM	65	225	80	starting
	12:15 PM	65	230	105	to brown (perfect)

4/1/2000	time	outside temp °F	oven temp °F	cook time min	food looks like
bread	10:30 AM	51	under 100	0	raw
	10:35 AM	51	105	5	“
	10:41 AM	51	120	11	“
	10:50 AM	51	160	20	“
	11:00 AM	52	180	30	rising
	11:20 AM	52	230	50	nice & puffy
	11:40 AM	53	225	70	“
	11:51 AM	53	230	81	“
	12:30 PM	54	230	120	cooking
	01:00 PM	54	250	150	“
	01:30 PM	55	235	180	“
	02:00 PM	56	240	210	browning
	02:30 PM	57	230	240	slightly
	03:00 PM	58	210	270	“
	03:30 PM	59	135	300	done

4/3/2000	time	outside temp °F	oven temp °F	cook time min	food looks like
bread	09:00 AM	39	under 100	0	raw
	09:10 AM	38	125	10	rising
	09:20 AM	39	150	20	“
	09:30 AM	40	170	30	nice & puffy
	09:45 AM	40	200	45	“
	10:00 AM	41	210	60	cooking
	10:30 AM	42	220	90	“
	11:00 AM	44	230	120	“
	11:30 AM	45	230	150	“
	12:00 PM	46	230	180	“
	01:00 PM	48	215	240	starting
	02:00 PM	49	205	300	to brown
	02:30 PM	50	205	330	“
	03:10 PM	52	230	370	done

7/30/2000	time	outside temp °F	oven temp °F	cook time min	food looks like
bread	09:30 AM	80	under 100	0	raw
	09:40 AM	80	150	10	“
	09:55 AM	81	180	25	rising
	10:15 AM	82	200	45	“
	10:30 AM	84	210	60	“
	11:00 AM	87	210	90	cooking
	11:30 AM	89	210	120	“
	12:00 PM	91	220	150	“
	12:30 PM	92	225	180	slightly
	01:00 PM	94	225	210	browning
	01:30 PM	95	230	240	“
	02:30 PM	95	220	300	done

8/19/2000	time	outside temp °F	oven temp °F	cook time min	food looks like
muffins	10:50 AM	88	under 100	0	raw
	11:11 AM	90	200	21	“
	11:36 AM	92	200	48	starting to puff
	12:00 PM	92	220	70	cooking
	12:28 PM	93	220	98	browning
	12:50 PM	94	225	120	done

8/24/2000	time	outside temp °F	oven temp °F	cook time min	food looks like
egg	09:55 AM	78	under 100	0	raw
	10:20 AM	81	160	25	cooking
	10:45 AM	84	200	50	almost done
	11:10 AM	85	210	75	overcooked

10/2/2000	time	outside temp °F	oven temp °F	cook time min	food looks like
bread	10:25 AM	65	under 100	0	raw
	10:35 AM	66	140	10	“
	10:50 AM	67	190	25	starting
	11:05 AM	68	215	40	to rise
	11:40 AM	71	230	75	plump
	12:10 PM	74	225	105	starting
	01:00 PM	77	225	155	to brown
	02:00 PM	76	225	215	browning
	02:30 PM	76	130	245	done

10/9/2000	time	outside temp °F	oven temp °F	cook time min	food looks like
muffins	09:30 AM	46	under 100	0	raw
	09:40 AM	48	100	10	rising
	10:00 AM	50	150	30	puffy
	10:15 AM	55	170	45	“
	10:40 AM	52	180	70	cooking
	11:00 AM	54	195	90	“
	11:20 AM	58	190	110	“
	12:00 PM	62	210	150	“
	12:30 PM	65	215	180	done

10/10/2000	time	outside temp °F	oven temp °F	cook time min	food looks like
egg	09:30 AM	54	under 100	0	raw
	09:45 AM	57	110	15	“
	10:00 AM	59	150	30	“
	10:20 AM	60	180	50	cooking
	10:40 AM	63	200	70	almost done
	10:50 AM	64	205	80	soft done

10/11/2000	time	outside temp °F	oven temp °F	cook time min	food looks like
bread	09:20 AM	58	under 100	0	raw
	09:35 AM	60	130	15	rising a bit
	09:50 AM	63	160	30	nice & puffy
	10:08 AM	65	185	48	“
	10:20 AM	65	175	60	“
	10:40 AM	66	185	80	cooking
	11:00 AM	67	205	100	“
	11:50 AM	70	210	150	“
	12:20 PM	71	220	180	“
	01:00 PM	74	230	220	browning
	01:40 PM	74	225	260	“
	01:50 PM	74	210	280	done

10/15/2000	time	outside temp °F	oven temp °F	cook time min	food looks like
bread	08:40 AM	47	under 100	0	raw
	08:58 AM	48	110	20	starting
	09:20 AM	50	140	40	to rise
	09:40 AM	52	150	60	cooking
	10:05 AM	53	170	85	“
	10:25 AM	55	175	105	“
	10:40 AM	56	175	120	“
	11:10 AM	58	190	150	“
	12:15 PM	62	210	215	“
	01:50 PM	66	180	300	collapsing
	02:22 PM	66	200	342	browning
	02:50 PM	67	210	370	a little
	03:40 PM	67	195	420	done

10/17/2000	time	outside temp °F	oven temp °F	cook time min	food looks like
bread	09:00 AM	54	under 100	0	raw
	09:20 AM	59	130	20	starting
	09:40 AM	60	150	40	to rise
	10:00 AM	59	165	60	rising
	10:30 AM	61	175	90	“
	11:00 AM	64	185	120	“
	11:40 AM	67	200	160	“
	12:00 PM	68	205	180	collapsing
	12:30 PM	69	210	210	“
	01:00 PM	70	210	240	cooking
	01:30 PM	71	215	270	“
	02:00 PM	72	215	300	“
	02:30 PM	72	210	330	browning
	03:00 PM	73	200	360	“
	03:30 PM	73	195	390	done

12/22/2000	time	outside temp °F	oven temp °F	cook time min	food looks like
bread	08:55 AM	49	under 100	0	raw
	09:25 AM	50	135	30	“
	09:55 AM	51	155	60	rising
	10:25 AM	52	130	90	“
	10:40 AM	52	155	105	“
	11:10 AM	53	140	135	“
	11:40 AM	53	130	165	maybe cooking
	12:20 PM	53	130	205	“
	12:50 PM	53	160	235	“
	01:20 PM	53	140	265	cooking
	02:05 PM	53	120	310	“
	02:25 PM	53	110	330	done on top, bottom gushy

12/26/2000	time	outside temp °F	oven temp °F	cook time min	food looks like
bread	09:35 AM	33	under 100	0	raw
	10:05 AM	35	130	30	“
	10:30 AM	37	160	55	rising
	11:05 AM	40	140	90	“
	11:50 AM	41	155	135	cooking
	12:03 PM	42	151	151	“
	12:30 PM	43	140	175	“
	12:45 PM	44	150	190	“
	01:55 PM	47	160	260	“
	04:44 PM	38	under 100	429	top done, bottom gushy

12/27/2000	time	outside temp °F	oven temp °F	cook time min	food looks like
egg	09:20 AM	43	under 100	0	raw
	09:30 AM	43	105	10	“
	09:50 AM	47	145	30	“
	10:25 AM	51	173	65	cooking nicely
	10:55 AM	53	160	95	“
	11:30 AM	56	160	130	“
	12:00 PM	59	152	160	“
	01:00 PM	59	135	220	“
	01:40 PM	60	160	260	done

1/2/2001	time	outside temp °F	oven temp °F	cook time min	food looks like
muffins	09:40 AM	41	under 100	0	raw
	10:00 AM	42	130	20	cooking
	10:26 AM	42	152	46	“
	11:05 AM	45	150	85	“
	11:30 AM	47	150	110	“
	12:25 PM	49	150	165	“
	01:20 PM	51	160	220	“
	02:10 PM	51	149	270	cooked on top, gushy on bottom