A Photometer for Measuring Population Growth in Yeast

Robert Tatina Tamela Hartley Danita Thomas

Baker's yeast (*Saccharomyces cerevisiae*), a versatile organism in the biology classroom, has been used to develop concepts about fermentation, asexual reproduction, and protozoan food vacuole function (Morholt et al. 1966). Because it is asexual and rapidly produces non-overlapping generations when cultured in nutrient solutions, it also can be used for studies of population growth (BSCS 1998). In these studies, individual cells are counted in samples taken from cultures at timed intervals. Plots of the numbers of individuals against time are then used to show the pattern of growth for the population. Alternatively, the size of these populations may be estimated photometrically. In this technique, light passing through a yeast culture is converted by a photoelectric cell into an electrical signal that is measured by a voltmeter (Morholt et al. 1966; Clarke 1998), the voltage produced by the photoelectric cell being inversely proportional to the light absorbed (and scattered) by the yeast. Of the two techniques, the photometric one is less time consuming.

In this paper we describe an easily constructed, inexpensive, portable photometer (Figure 1) designed specifically for estimating population sizes in yeast cultures. We then describe how to use the photometer. Finally, we suggest some research questions that may be answered about yeast specifically and populations generally by using this photometer.

Constructing the Photometer

The parts used in the photometer are as follows:

Robert Tatina is a Professor, and **Tamela Hartley** and **Danita Thomas** are students in the Biology Department at Dakota Wesleyan University, Mitchell, SD 57301.

- 6″ × 3″ × 2″ project enclosure (Radio Shack #270-1805)
- 7/8″ O.D. × 3/4″ I.D. PVC tubing
- 2 cm × 4 cm silicon solar cell (Radio Shack #276-124A)
- Momentary pushbutton switch (Radio Shack #275-1547C)
- 4 solderless banana plugs (Radio Shack #274-721)
- 2 insulated banana jacks (Radio Shack #276-725B)
- AA battery holder (Radio Shack #270-408)
- Lamp holder (Radio Shack #272-360)
- 2.33-Volt prefocus lamp (Radio Shack #272-1124)
- Digital voltmeter (e.g. Radio Shack #22-802 or 22-803)
- 35 mm film canister
- 1″ pine stock
- #26 AWG stranded copper wire, insulated

1. From a 1″ stock piece of wood (1″ stock = 3/4″ thick) cut a rectangle that is 2-7/8″ long by 2-3/8″ wide. This piece will serve as the base (Figure 2).
2. Drill a 7/8″ hole with a center located 3/4″ from the 2-3/8″ end and 1-5/16″ from the 2-7/8″ side.
3. From another piece of 1″ stock, cut a 1-15/16″ × 1-3/8″ rectangle. This will serve as a support for the solar cell. In one of the broad faces cut a 1/4″ deep mortise that extends across the length from one side inward 3/4″ (Figure 2).
4. Cut a 4-3/4″ length of PVC tubing and drill through it a 3/8″ hole with a center 1″ from one end, smoothing all cuts with fine sandpaper.
5. Insert the PVC tubing, hole end first, into the 7/8″ hole in the base until the end of the tubing is flush with the bottom of the base. Then rotate the tubing until the centerline of the 3/8″ hole is parallel to the length of the base.
6. Glue the mortised side of the solar cell support described in Step 3 to the short side of the tubing end of the base, making sure this piece is centered (Figure 3). This will leave about a 1/16″ gap between the face of the support and the tubing.
7. Carefully solder 6″ lead wires (#26 AWG) to the terminals of the solar cell. Then, using silicon sealant, affix the solar cell to the face of the solar cell support with the blue side of the solar cell facing the tubing.
8. With a small wood screw affix the lamp holder to the base so that the bulb points into the hole in the PVC tubing. The bulb should just clear the tubing.
9. Solder a 6″ lead wire to one of the terminals of the lamp holder.
10. Drill two 5/16″ holes into the side of the project enclosure for the banana jacks. Their location (Figure 3), while not critical, should avoid objects inside the photometer. Insert the jacks and tighten them in place.
11. Insert the base into the project enclosure so that the solar cell support is at one end of the enclosure (Figure 3).
12. Solder each lead from the solar cell to a separate banana jack.
13. Slide the battery holder into the enclosure immediately behind the base.
14. On a centerline drawn along the length of the project enclosure lid, mark a center for the 7/8″ PVC tubing hole 1-5/8″ from one end and a center for the 3/8″ switch hole 3-1/2″ from the same end. Drill these holes.
15. Install the momentary switch and tighten it in place.
16. To complete the lamp circuit (Figure 3), connect and solder the 6″ lead wire from the lamp holder to one of the terminals of the switch. Then solder a wire from the battery holder to the other switch terminal.

Downloaded from http://online.ucpress.edu/abt/article-pdf/61/8/625/49220/4450781.pdf by guest on 15 June 2021

Figure 1. Photometer connected to voltmeter.

Connect and solder the second battery holder wire to the open lamp holder terminal.

17. Install the lid and place a black 35 mm film canister over the open end of the PVC tubing.
18. After constructing two leads from 12″ lengths of #26 AWG stranded copper wire and banana plugs, connect these between the banana jacks on the voltmeter and those on the photometer.

Using the Photometer

Test the photometer by pressing the momentary switch that turns on the lamp. The voltage indicated on the voltmeter should be positive. If not, interchange the banana plugs. (Our photometers have produced about 0.380V with nothing in the light path.) Then, insert a blank tube (a culture tube that contains nutrient medium without organisms) into the PVC tubing, making sure that the tube is clean on the outside. Install the film canister over the top of the PVC tubing and record the voltage after holding down the momentary switch for 5 seconds. Repeat this procedure for a tube that has a yeast-containing medium after homogenizing the contents of the tube. (Because homogenizing the culture is critical for repeatable measurements, we use screw cap culture tubes, allowing us to completely homogenize the culture by shaking the tube.) Then calculate the absorbance of light by the

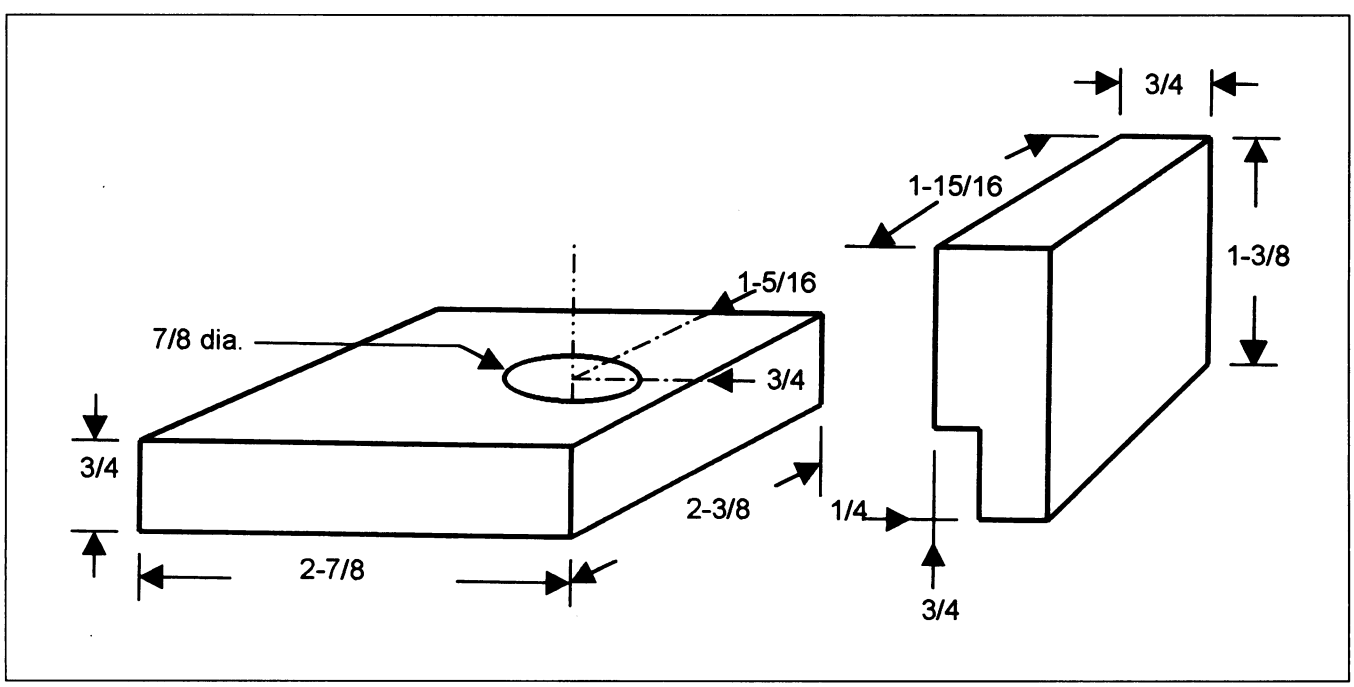

Figure 2. Base (left) and solar cell support (right). Both pieces are cut from 1-inch stock boards. All measurements are in inches.

Downloaded from http://online.ucpress.edu/abt/article-pdf/61/8/625/49220/4450781.pdf by guest on 15 June 2021

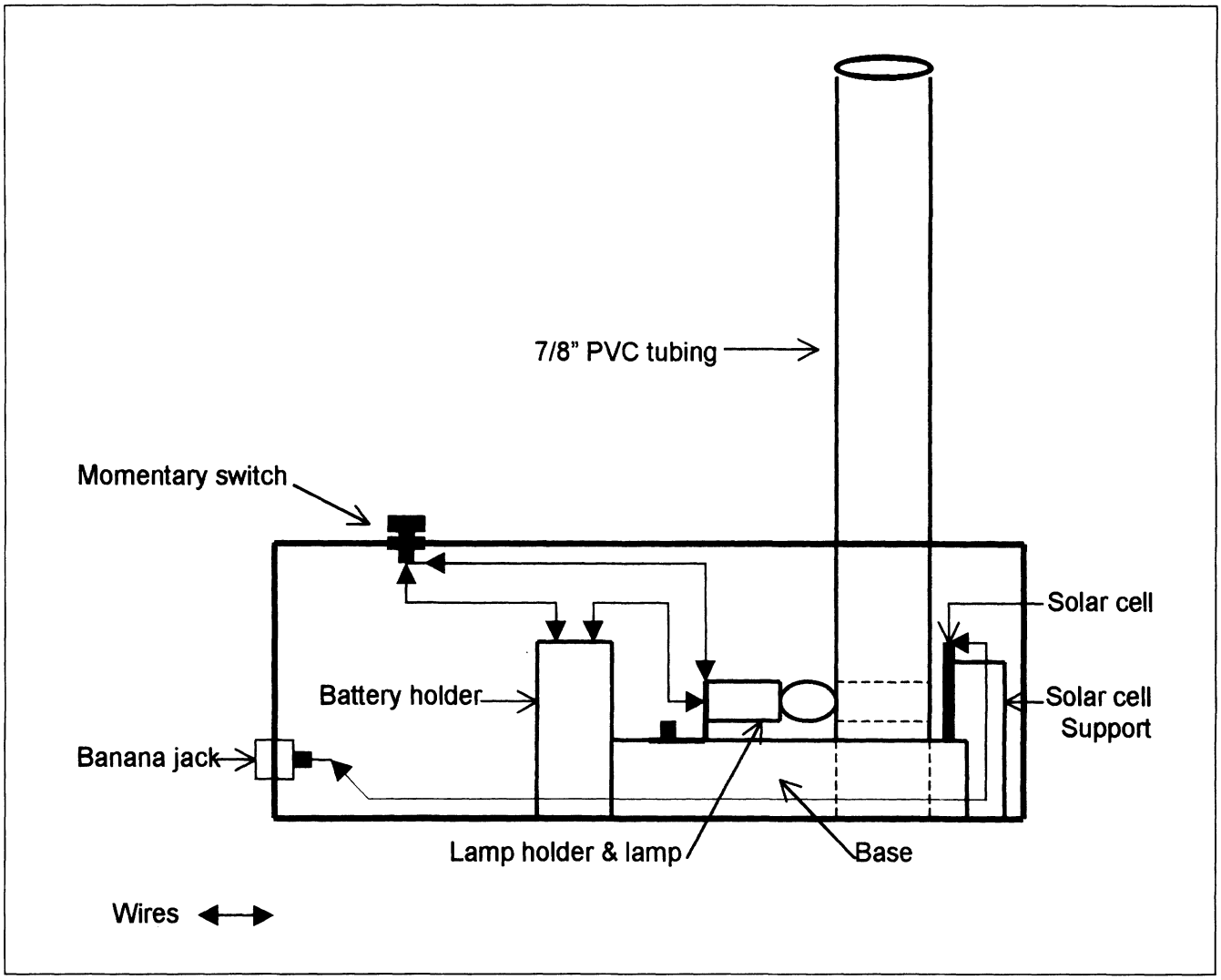

Figure 3. Photometer in phantom side view.

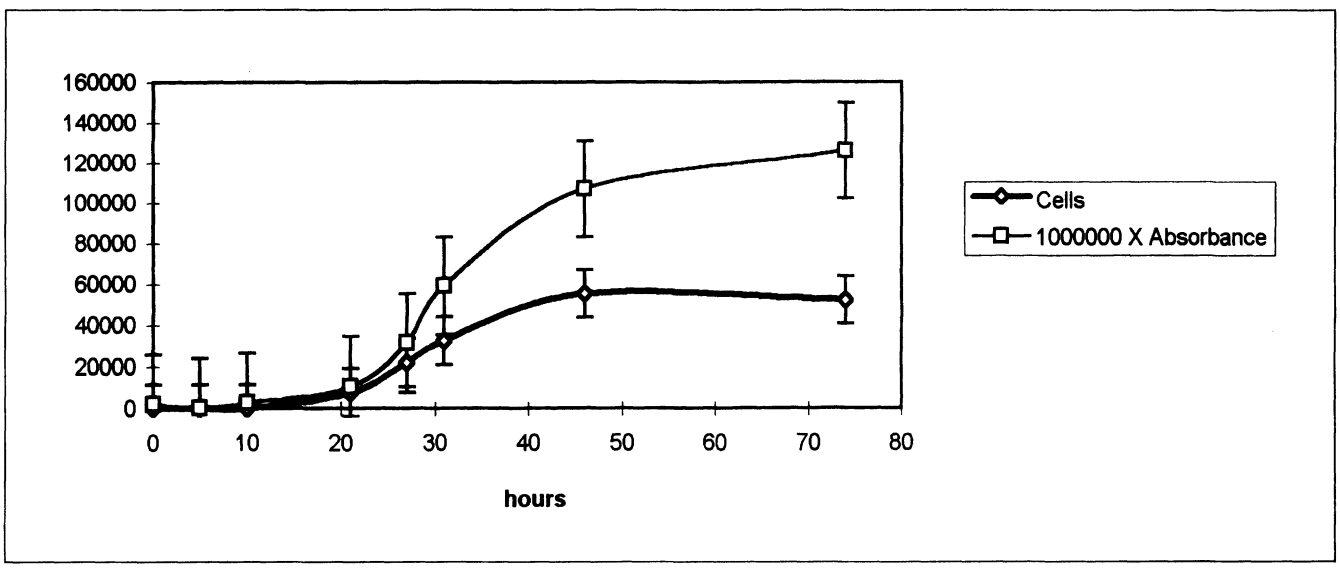

Figure 4. Growth curves of yeast in 10 mL cultures grown at 37° C. Data are means and standard errors for absorbances and hemacytometer cell counts in 0.1 mL samples taken from three replicate cultures. The absorbance values were multiplied by 10^6 so that both plots could use the same scale on the Y-axis.

Downloaded from http://online.ucpress.edu/abt/article-pdf/61/8/625/49220/4450781.pdf by guest on 15 June 2021

following: Absorbance = log (blank voltage/culture voltage).

Testing the Photometer

Because the absorbance of light is due to several factors (e.g. in yeast growth experiments—cell number, cell size and cell opacity), we decided to determine whether it was correlated with increases in number of yeast cells. To do this we raised yeast cultures at 20° C in 10 mL of a sterile nutrient broth prepared by dissolving 2.5 g yeast extract, 2.0 g monobasic potassium phosphate, 40.0 g glucose, and 5.0 g peptone in 1000 mL of distilled water (Behringer 1973). Each culture tube was initiated by adding one drop of a 24-hour yeast culture. After being homogenized, one drop of culture was removed to a hemacytometer and counted at 400X. Three replicate cultures were counted at intervals over 74 hours. Transmittance voltages for blanks and cultures were measured on the same tubes after the contents of each were homogenized.

Figure 4 shows the plots of cell counts and absorbances. Because these two variables were highly correlated ($r = 0.975$, $p < 0.001$), absorbance can be used in place of actual counts to show population growth over time.

In addition to demonstrating growth curves, this photometer may be used to answer a number of research questions regarding yeast. Some of these are: How does temperature affect the growth of yeast? How do different food sources (sugars) and amount of resources (sugar concentrations) affect the growth of yeast? How does resource space (volume of culture medium) affect the growth of yeast? How do environmental pollutants (e.g. lead, mercury, etc.) affect the growth of yeast? How do water-soluble vitamins affect the growth of a yeast population? How does accumulation of metabolic waste (alcohol) affect the growth of yeast?

References

Behringer, M.P. (1973). *Techniques and Materials in Biology*. New York: McGraw-Hill.

Biological Sciences Curriculum Study. (1998). *BSCS Biology: An Ecological Approach*, 8th ed. Dubuque: Kendall/Hunt Publishing Co.

Clarke, D.W. (1998). Shoebox spectroscopy. *The Science Teacher, 65*(7), 28–31.

Morholt, E., Brandwein, P.F. & Alexander, J. (1966). *A Sourcebook for the Biological Sciences*, 2nd ed. New York: Harcourt, Brace and World, Inc.

STEPS OF THE SCIENTIFIC METHOD

(IN A SYNESTHETIC MODE)

Red is the idea, the starting flare, the spark.
Lightning slicing through the air, a shiver in the dark.
Orange is the hypothesis, confused but gliding down a path.
Subject to uncertainties' glare, but always changing with burning wrath.
Yellow holds the power of experiments and data.
The light to prove right or wrong. But being squished right in the middle.
It only gets to ring the gong.
Turquoise analyzes facts, and is of two minds, **Green** and **Blue**.
One strong and sturdy, a decisive mind; and one caring, gentle, true;
Black is the conclusion, dark is the illusion, cradled in the massive sky
Of the Scientific Method paradise.
All colors gone unmentioned, **Brown**, **Purple**, **Pink** and **White**
Are left to their own invention, to paint a scientist's delight.

Sarah M. DeGeorge
Woodland Community College 1999

Downloaded from http://online.ucpress.edu/abt/article-pdf/61/8/625/49220/4450781.pdf by guest on 15 June 2021