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University of Wyoming Agricultural Experiment Station

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ARTIFICIAL INCUBATION AT HIGH ALTITUDES
By Frank J. Kohn

INTRODUCTION

It is generally believed that results in hatchability are lower in the dry climate of the mountain states than in the humid areas near sea level. This is not only believed to be true in artificial incubation but under many conditions of natural incubation as well. For the past five years the Wyoming Agricultural Experiment Station has conducted experiments in artificial incubation in an effort to determine the causes of low hatchability. These experiments included studies in selection, care, and management of the breeding flock; the selection and routine management of incubators; and feeds in relation to hatchability.

Experiments in artificial incubation were started with six breeds of chickens: Single Comb White Leghorn, Barred Plymouth Rock, Single Comb Rhode Island Red, White Wyandotte and Black Langshan. Later work and results given in this bulletin included only the White Leghorn.

Two types of houses were used in the experiments, semimonitor long house and unit type shed roof house. The long house consisted of six pens 20'x20' in size. The eight unit houses ranged in size from 12'x12' to 16'x24'. At the beginning of the experiment both types contained straw insulated and non-insulated pens. In later work all pens were straw insulated and in addition three pens were steam heated. The various pens were ventilated by means of muslin curtains, burlap curtains, lath bafflers, stack ventilation, window ventilation, and little or no ventilation except on nice days.

All work in incubation was conducted in the basement of the Poultry Building, located on the University Stock Farm near Laramie. The incubator room was well adapted for the work, both as to uniformity of temperature and of humidity. Efficient ventilation was provided by means of a stack and burlap curtains. The seven makes of incubators varied in size from 150 to 500 eggs. Two of these makes were of the hot air diffusion type and five makes were of the hot water radiation type.
THE BREEDING FLOCK

During the spring season when the breeding flock is on range and receives abundant warm sunshine, tender succulent greens, and outdoor exercise, good hatchability is a natural condition. Commercial incubation and brooding, however, must be well advanced long before the natural spring season. For this reason, spring conditions must be substituted in the form of comfortable housing, feeding of substitute greens, inducing exercise, as well as other consideration in management. The following discussion on the selection, care, and management of the breeding flock is based on experimental results from this Station and are given here to show the system of management in use in the experiment.

Selection. In the selection of breeding stock constitutional vigor must receive first consideration. It is fundamental to high fertility, high hatchability, high livability of the chicks, and to high egg production.

The external evidences of constitutional vigor are indicated by a well-developed, well-fleshed body; a healthy, thrifty appearance; a bright red comb and wattles; a neat, trim, well-proportioned head; a clear, prominent eye, and glossy plumage. Constitutional vigor is also indicated by the activity of the birds. The inactive, droopy, and sleepy birds are usually birds of low vitality and should not be used for breeders.

It is understood that the stock should be of standard type, weight, color, and both male and female of high production ancestry.

Breeding. High hatchability is inherited. Selection of breeding stock, both male and female, should be from hens which have given high hatchability.

Males. The number of females to mate with one male depends largely upon the male's age and vigor. For the light breeds, from twelve to fifteen females to one male, for the American breeds from ten to twelve, and for the heavy breeds from six to eight, are considered advisable.
Age of Breeding Stock. The age of the breeding stock is frequently a factor in hatchability. Birds two years old or older must be vigorous and outstanding individuals to deserve a place in the breeding pen. The best hatchability is obtained from younger birds almost without exception. The matings which have given the best results over a period of five years' investigation at the Wyoming Experiment Station are ranked in the following order:

a. Yearling hens mated to well-developed, vigorous cockerels.
b. Well-developed pullets mated to vigorous cock birds.
c. Yearling hens mated to cock birds.

Feeding. The ration for the breeding stock does not need to be different from that of the laying flock. It is important that the ration be well supplemented with feeds such as yellow corn and greens. It is also important that the breeding flock should have frequent access to direct sunlight or receive cod-liver oil as a supplement to the ration.

a. Mash. The animal protein of the laying mash is best reduced to 10 per cent and in addition two to three gallons of skim milk supplied to each 100 hens per day.

b. Scratch feed. From 12-14 pounds of scratch feed should be fed per 100 hens per day. Feeding, however, must be according to the condition of the hens rather than according to rule. Breeding stock should not be forced for egg production.

c. Green feed substitutes. The green feed substitutes used in experimental rations to date have been alfalfa, cabbage, sunflower silage, sprouted oats, wheat and barley (sprouts from one-half inch to one inch in length).

Exercise. Exercise is an important factor in keeping hens healthy and thrifty and in maintaining them in breeding condition. They should be fed so as to induce them to exercise in the house as well as on the range.

Parasites. Parasites undermine the health of the hens. If the hens are kept free from lice and intestinal parasites and the house is kept clean and free from mites, the best results will be obtained.
Condition. Birds kept in good flesh, but not fat, will give the best hatchability. Male birds frequently get out of condition during the breeding season. Grain should be supplied in small hoppers just out of reach of the hens. This will keep male birds from starving themselves because of attentiveness to the hens.

Housing. Comfortable housing is essential in maintaining the health of the breeding flock. Comfort implies a uniform temperature, warmth, freedom from draftiness, freedom from dustiness, and protection against sudden temperature changes.

Rest. Hens that are to be used in the breeding flock should have a rest from egg production for at least two months or long enough to recover pigmentation.

INCUBATION

Selection of Eggs. In the selection of hatching eggs the factor of vigorous health in the breeding stock is by far the most important. In addition to this the selection of hatching eggs should be largely from the standpoint of market demands for market eggs. Eggs that are small, oversize, spherical, elongated, are all equally undesirable. Eggs for hatching should be uniform in size, shape, and color. The shell should be strong, with smooth and even texture, and free from ridges and other abnormalities. Eggs that weigh 24-28 ounces to the dozen, free from tints, smooth and even shell texture, and approximately pear-shaped, have been found to be most desirable for hatching as well as for the market.

Care of Hatching Eggs. In order to prevent unnecessary losses from cracking, breaking, soiling, or freezing, hatching eggs should be gathered soon after they are laid and stored in a basement or other cool place of uniform temperature. Incubation begins at about 70° F. The most favorable temperatures for hatching eggs in storage have been placed between 50° and 60° F. However, eggs have been stored at temperatures down to 32° F. without lowering the hatchability. The danger to hatching eggs seems to be greater at 70° F. or above than at temperatures near freezing.
Age of Hatching Eggs. Experimental results conducted at this station during 1924 show that the age of hatching eggs is an important factor in hatchability. Eggs were held in storage from one day up to twenty-one days at temperatures of 40° to 60° F. This work has demonstrated that hatching quality of eggs is lowered very little in eight to ten days. After eight to ten days of age the hatching quality deteriorated very quickly.

Turning of Hatching Eggs. Experimental results in turning hatching eggs are based on one season's work. Twelve hundred eggs were held in storage for ten days, half of which were turned once daily. There were no significant differences in hatchability in favor of turning.

Kind of Incubator. The choice of an incubator is not always an easy task. Most of the incubators on the market are more suitable for humid areas than for our high altitudes and dry climate. Experimental work at the Wyoming Agricultural Experiment Station has demonstrated that better results may be expected from those incubators in which direct provision is made for moisture supply through the use of sand trays or other features. In buying an incubator the following factors should be taken into consideration.

1. Adequate insulation.
2. Sufficient heat supply for efficient operation in an incubator room with temperatures as low as 40° F.
3. Provision for accurate heat control.
4. A good ventilation system.
5. A moisture supply system.

Location of the Incubator. A good incubator room is a very important factor in the successful operation of the incubator. A good room helps in maintaining correct conditions of moisture and temperature, saves labor, and makes the operation of the incubator easier. Briefly, the following should be factors in the choice of an incubator room:
1. Uniform temperature. Basement rooms are usually more satisfactory than rooms above the ground. Basement rooms give protection against sudden temperature changes and show little fluctuation in temperature between day and night.

2. Moisture. Correct moisture conditions are necessary for best results. These can usually be maintained more satisfactorily in a basement room with dirt or concrete floor.

3. Ventilation. In addition to moisture and uniform temperature, the incubator room should be well ventilated. The ventilation system to be adopted will depend somewhat on the natural protection afforded by farm building, hedges, or windbreaks. Cross currents from window to window, or door to window, as well as floor drafts, must be avoided. The most efficient ventilation is obtained by means of a ventilation stack and muslin curtains over the window frames. This will prevent drafts and assure a steady flow of fresh air.

**Leveling the Incubator.** The incubator must be level in order to have a reasonably uniform temperature on all parts of the egg tray.

**Cleaning and Disinfection.** Incubators that have been used the previous season should be cleaned and disinfected with a 3 to 5 per cent solution of a standard coal tar stock dip. In addition to this the incubator should be disinfected after each hatch in order to protect subsequent hatches against disease infection which may be present in the incubator.

**The Lamp.** Smoky lamps and the deposition of soot in the heating system may cause considerable trouble to the operator. A good grade of oil should be used and the lamp kept clean. The accumulation of carbon should be removed once daily, and the wick trimmed so that a clean, well-rounded and maximum flame is possible. Starting the lamp with a flame of medium height will prevent smoking due to creeping up of the flame. Final adjustment can be made after the lamp is thoroughly heated.
Operation of the Incubator. No attempt is made here to give detailed directions for operating the different makes of incubators. The manufacturer’s directions are usually complete and should be followed closely by the inexperienced operator. Whatever changes in directions are necessary due to high altitude climatic conditions are indicated in the following discussion.

Turning the Eggs During Incubation. There are several advantages in turning eggs during incubation. Turning the eggs prevents the embryo from adhering to the shell membrane, changes the position of the egg on the tray and compensates for differences in temperature, and thereby, to a certain extent, increases the hatchability.

Number of Turnings. At the Wyoming Agricultural Experiment Station eggs were turned two, four, six and eight times a day (see table No. 1) in order to determine the effect on hatchability. All other factors, such as moisture, temperature, and ventilation, were kept reasonably constant. The results from sixteen incubators indicate that nothing is gained by turning the eggs six and eight times a day. These results further indicate that the gains derived from four turnings over two turnings a day are somewhat questionable, since the average percentage increase of four turnings over two was found to be only 3.7 per cent.

<table>
<thead>
<tr>
<th>TABLE I</th>
<th>Number of Turnings a Day in Relation to Hatchability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Two</td>
</tr>
<tr>
<td>1st Trial</td>
<td>38.0</td>
</tr>
<tr>
<td>2d Trial</td>
<td>49.2</td>
</tr>
<tr>
<td>3d Trial</td>
<td>56.0</td>
</tr>
<tr>
<td>4th Trial</td>
<td>54.8</td>
</tr>
</tbody>
</table>

Cooling of Eggs During Incubation. The experiments in the cooling of eggs during incubation covered a period of three years. During the first part of this period the experiments were conducted at incubation temperatures as recommended by the manufacturers. Later work included incubation temperatures which were from 1° to 2° higher and from 1° to 2° lower than recom-
mended for the make of incubator. Seven makes of incubators were used, varying in size from 150 to 500 eggs.

The eggs were cooled by subjecting them to room temperature until they felt cool to the touch. At the higher temperatures the eggs were cooled twice a day and at the lower temperatures they were cooled once. Eggs were cooled from the third day to the eighteenth day of incubation, inclusive.

When the average temperature of incubation at the top level of the eggs was 102½° to 103½°, inclusive, the results were in favor of cooling, both as to hatchability of the eggs and livability of the chicks. On eighteen trials at the above temperatures, cooling of eggs gave 11.2 per cent better hatchability than no cooling.

At an average temperature of 102°, the results in favor of cooling were not significant. On six trials the cooled eggs gave 3.0 per cent better hatchability of the eggs than no cooling.

At an average temperature of 101½° to 102°, inclusive, the hatchability was favored when the eggs were cooled.

The experimental work has demonstrated that the cooling of eggs during incubation is valuable especially at the higher temperatures because it is necessary to remove the excess animal heat and to prevent abnormally rapid embryonic growth. Incubators for which the cooling of eggs was recommended gave fully as good results without cooling when operated at lower temperatures. All work with incubation temperatures in this bulletin is based on a relative humidity of 50 per cent within the incubator.

*Temperature.* The correct temperature for incubation depends upon the place of measurement such as the position of the thermometer in the incubator, the height of the thermometer bulb above the egg tray, and whether the thermometer bulb is in contact with the eggs or not. In addition to these the factor of humidity in relation to temperature is of considerable importance.

The first experiments were conducted with the thermometer bulb 1¼ to 1½ inches from the egg tray and in contact with two eggs. Eggs were cooled once daily. The following table gives the different temperatures for incubation as well as the hatching time:
TABLE II

| Temperatures for 1st, 2d, and 3d Weeks of Incubation | Number of Incubators | Hatch Complete | Variation from Normal*
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>101-102-103</td>
<td>3</td>
<td>21½ days</td>
<td>Slight</td>
</tr>
<tr>
<td>101½-102-103</td>
<td>3</td>
<td>21 days</td>
<td>None</td>
</tr>
<tr>
<td>102-102½-103</td>
<td>3</td>
<td>20 da. 21 hrs.</td>
<td>None</td>
</tr>
</tbody>
</table>

*Normal hatching time was determined from eighteen hens set under different nesting conditions. The variation in hatching time was between 19½ and 21 days.

No difference in hatchability could be observed with the temperatures shown in Table II. The eggs were turned twice a day and cooled once a day from the third to the eighteenth day, inclusive. The relative humidity in the incubators varied between 45 and 50 per cent.

Other temperature experiments were conducted with the top of the thermometer bulb from 1¼ to 1⅝ inches from the egg tray. For this type of thermometer the temperature of 102°, 103°, and 104° F. for the first, second, and third weeks, respectively, compared favorably with the normal hatching time. A double check on incubation temperatures was made by a study of embryonic development. Embryos were removed at different stages of development and compared with the embryonic development in natural incubation. The "Development of the Chick," by Lillie, was used as a basis for making comparisons.

Experiments conducted at this experiment station show a direct relationship between the egg temperature and the relative humidity in the incubator. In studying the effect of relative humidity on egg temperature, thermometer bulbs were placed in the normal position of the embryo inside the egg. The opening through which the thermometer bulb was introduced was sealed with paraffin. By varying the relative humidity and keeping the incubator temperature constant, differences in egg temperatures of .5° F. to 1.3° F. were observed.

Moisture. Eggs lose a certain percentage of moisture during incubation. This amount varies with the ventilation system of the incubator, the relative humidity, the temperature, air pressure, and the egg. The dry climate of this region makes it especially difficult to maintain proper moisture conditions. Several experiments were
conducted to determine the most favorable moisture conditions for both natural and artificial incubation. Hens were set under the following nesting conditions:

Nest No. 1. Straw nest on the concrete floor.
Nest No. 2. Damp soil in the bottom of the nest. Top of the nest lined with straw and chaff.
Nest No. 3. Gravel nest with no other nesting material. Gravel moistened twice during the hatch.
Nest No. 4. Nest lined with chaff built on the dirt floor of the house.

Hens were set on nests 1 to 4, inclusive, during both early spring and mid-summer. No appreciable difference in hatchability was observed during the spring months. During the summer nests Nos. 2, 3 and 4 gave better results than No. 1. The best hatchability was obtained from eggs that showed a loss in weight of 10.8 per cent to 13.4 per cent for eighteen days of incubation. A total of eighteen hens were set.

Incubators were operated so that the moisture loss from the eggs was approximately the same as given under natural incubation. Eggs were weighed at regular intervals and the percentage loss calculated. Individual weight records were also kept on ten to twenty eggs in each incubator tray in order to study the variation in loss in weight. Table No. III gives the hatchability in the same make of incubator under different moisture conditions.

<table>
<thead>
<tr>
<th>Incubator No.</th>
<th>Moisture Loss</th>
<th>Fertile Eggs</th>
<th>Chicks Hatched</th>
<th>Percentage Hatched</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>14.6</td>
<td>398</td>
<td>235</td>
<td>59</td>
</tr>
<tr>
<td>2</td>
<td>15.3</td>
<td>414</td>
<td>257</td>
<td>62</td>
</tr>
<tr>
<td>3</td>
<td>12.7</td>
<td>427</td>
<td>282</td>
<td>66</td>
</tr>
<tr>
<td>4</td>
<td>12.3</td>
<td>412</td>
<td>267</td>
<td>65</td>
</tr>
<tr>
<td>5</td>
<td>18.7</td>
<td>478</td>
<td>132</td>
<td>30.5</td>
</tr>
<tr>
<td>6</td>
<td>22.3</td>
<td>466</td>
<td>85</td>
<td>18.3</td>
</tr>
</tbody>
</table>

During our five years of experimental work in artificial incubation, it has been demonstrated many times that the best hatchability is obtained when the loss in weight for eighteen days of
incubation is between 12 and 13 per cent. This loss in weight is for eggs that are ten to twelve days old when incubation starts and is indicated in Table III. For eggs three to four days old, it was found that a loss in weight varying between 12 and 15 per cent did not seem to make any difference in hatchability.

<table>
<thead>
<tr>
<th>Initial Weight Grams</th>
<th>Weight at 3 Days</th>
<th>Weight at 5 Days</th>
<th>Weight at 10 Days</th>
<th>% Loss for 10 Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>63.245</td>
<td>62.910</td>
<td>62.700</td>
<td>62.050</td>
<td>1.88</td>
</tr>
<tr>
<td>54.000</td>
<td>53.745</td>
<td>53.585</td>
<td>53.170</td>
<td>1.54</td>
</tr>
<tr>
<td>55.900</td>
<td>55.900</td>
<td>55.700</td>
<td>55.110</td>
<td>1.97</td>
</tr>
<tr>
<td>55.200</td>
<td>54.915</td>
<td>54.730</td>
<td>54.205</td>
<td>1.89</td>
</tr>
<tr>
<td>60.890</td>
<td>60.575</td>
<td>60.420</td>
<td>59.895</td>
<td>1.63</td>
</tr>
<tr>
<td>56.445</td>
<td>56.135</td>
<td>55.940</td>
<td>55.355</td>
<td>1.93</td>
</tr>
<tr>
<td>53.930</td>
<td>53.675</td>
<td>53.490</td>
<td>53.095</td>
<td>1.73</td>
</tr>
<tr>
<td>51.310</td>
<td>51.080</td>
<td>50.940</td>
<td>50.515</td>
<td>1.54</td>
</tr>
<tr>
<td>49.850</td>
<td>49.605</td>
<td>49.440</td>
<td>48.965</td>
<td>1.77</td>
</tr>
<tr>
<td>66.140</td>
<td>65.795</td>
<td>65.525</td>
<td>64.870</td>
<td>1.92</td>
</tr>
</tbody>
</table>

Average Moisture Loss: 1.76

Table No. IV gives the losses in weight from eggs stored in the incubator basement. Weight records were kept on several hundred eggs, and ten eggs were selected for this table. During the time these records were kept, the basement was unheated. The temperature varied between 47 and 50 degrees F. and the relative humidity between 26 and 35. At this variation in temperature and humidity, the loss in weight from the eggs was approximately one per cent for every five and one-half days that the eggs remained in storage, or 1.54 to 1.97 per cent at the age of ten days, the time incubation started. Table V gives the loss in weight during incubation as well as the variation in loss in weight of eggs in the same incubator. The average relative humidity was 52 per cent and the average incubation temperature 102½° F.

Methods of Supplying Moisture. Moisture is commonly supplied by means of sand trays, water trays, wet sponges, sprinkling the eggs, or by moistening the inside of the incubator. Our experiment shows that the sand tray supplies moisture more uniformly and with less temperature fluctuation than sprinkling of the eggs or moistening the inside of the incubator. However, additional
moisture is needed for good hatchability and this is best supplied by placing wet sponges on the egg tray. During sub-zero weather as well as during some mid-summer weather it has been found necessary to place shelves with wet sponges above the egg trays to maintain correct moisture conditions.

_Ventilation._ Evaporation from the eggs may be checked by reducing the ventilation in the incubator, by increasing the moisture or both. Under some conditions the hatchability has been improved by reducing the ventilation. Experiments with the ventilation of incubators have demonstrated that better hatchability is obtained when the rate of evaporation from the eggs is controlled by increasing or decreasing the moisture in the incubator than by changing the ventilation.

_The Factor of Variation._ There are, no doubt, many factors which cause a variation in hatchability. Experiments in incubation have shown that a certain degree of variation exists even though all factors concerning the breeding stock, feeds, the eggs, and incubation are as nearly the same as it is possible to get them. This variation in hatchability is called normal variation in this bulletin. The experimental work in normal variation helped to interpret more accurately other factors in hatchability.

Two standard makes of incubators were used in the experiment. The eggs were divided equally as to pen, age, size, shape,
Jan. 1930 Artificial Incubation at High Altitudes

and shell texture. All conditions of incubation such as cooling, moisture, and turning of eggs were the same. The maximum variation in the completion of the hatch in all incubators used was a little less than three hours, and the maximum variation in moisture loss among the incubators in any one trial was 1.25 per cent. Table VI gives the variation in hatchability.

### TABLE VI

**Variation in Hatchability**

<table>
<thead>
<tr>
<th>Incubator Number</th>
<th>1st Trial 1927</th>
<th>2nd Trial 1927</th>
<th>3rd Trial 1928</th>
<th>4th Trial 1928</th>
<th>5th Trial 1929</th>
<th>6th Trial 1929</th>
<th>7th Trial 1929</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>56.6</td>
<td>53.3</td>
<td></td>
<td></td>
<td>54.0</td>
<td>63.0</td>
<td>71.6</td>
</tr>
<tr>
<td>2</td>
<td>48.9</td>
<td>49.2</td>
<td>42.4</td>
<td>51.0</td>
<td>49.8</td>
<td>59.7</td>
<td>76.0</td>
</tr>
<tr>
<td>3</td>
<td>45.0</td>
<td>46.6</td>
<td>42.8</td>
<td>56.4</td>
<td>56.4</td>
<td>61.5</td>
<td>78.0</td>
</tr>
<tr>
<td>4</td>
<td>47.5</td>
<td>48.3</td>
<td>44.8</td>
<td>53.1</td>
<td>61.5</td>
<td>78.0</td>
<td>75.4</td>
</tr>
<tr>
<td>5</td>
<td>60.0</td>
<td>52.8</td>
<td>56.4</td>
<td>49.2</td>
<td>50.8</td>
<td>65.4</td>
<td>73.9</td>
</tr>
</tbody>
</table>

For the first and second trials the average number of fertile eggs per incubator was 92. For the third to seventh trials, inclusive, the average number of fertile eggs per incubator was 124. The third trial differs from the rest in that the division of eggs for the two incubators was made according to hens. Each incubator contained the same number of eggs from each hen.

The variation in hatchability in the first and second trials was 11.6 per cent and 11.7 per cent, respectively. The third trial shows the least variation or 3.6 per cent. The variation in the fourth to seventh trials, inclusive, ranges from 6.6 per cent to 7.8 per cent and is representative of the variation in other trials not given in Table VI.

**FEEDING IN RELATION TO HATCHABILITY**

*Green Feeds Substitutes.* The problem of producing hatchable eggs in this climate is much the same as that of producing winter eggs. Both are directly related to management and feeding and both require liberal quantities of green feed or their substitutes. In the climate of this region, it is necessary to supply the green feed substitutes for seven and one-half to eight months of the year.
The green feed substitutes that were used in the hatchability experiments were sprouted barley, cabbage, sunflower silage and alfalfa leaves. Cod-liver oil was also used as a supplement to the ration. The basal ration of the pens consisted of 200 pounds finely-ground barley, 100 pounds finely-ground wheat, 100 pounds mill run, 100 pounds meat scrap (50 per cent protein), and three pounds salt. The scratch feed consisted of 200 pounds barley, 100 pounds heavy oats and 100 pounds wheat.

The sprouted barley, cabbage, and sunflower silage were fed once daily at the morning feeding. Alfalfa leaves were available in hoppers all the time. From three to four pounds of sprouted grain were fed to 100 hens. The sunflower silage pens received all the silage they would consume at one feeding. This amount was three pounds per day for the first month and increased to five pounds per day by the third month of the experiment. From five to six pounds of shredded cabbage were fed per day per 100 hens from November to March, inclusive.

The first hatchability tests were made February 1st, or three months after the start of the experiment. The results are given in Table VII. In these tests sunflower silage seems to have added little or nothing to the basal ration. In succeeding tests made two months later (See Table VIII) the hatchability of the sunflower silage pen had increased considerably while that of the basal ration had decreased.

**TABLE VII**

<table>
<thead>
<tr>
<th>Effect of Green Feed Substitutes in the Barley Ration</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Incubators</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Number of Eggs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set February 1st</td>
<td>300</td>
<td>450</td>
<td>450</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>Per Cent Fertility</td>
<td>82</td>
<td>84</td>
<td>82</td>
<td>85</td>
<td>84</td>
</tr>
<tr>
<td>Per Cent of Fertile Eggs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eggs Hatched</td>
<td>31.8</td>
<td>56.6</td>
<td>46.4</td>
<td>34.5</td>
<td>58.8</td>
</tr>
</tbody>
</table>
Jan. 1930 Artificial Incubation at High Altitudes

In other hatchability tests the following basal ration was used:
200 pounds finely-ground corn; 100 pounds finely-ground wheat,
100 pounds mill run, 100 pounds meat scrap, three pounds salt; the
scratch feed, 200 pounds corn, 100 pounds wheat, 100 pounds oats.
The results in Table X are not to be compared with the barley
rations in Tables VIII and IX, since these were not used in the
same year.

<table>
<thead>
<tr>
<th>TABLE VIII</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effect of Green Feed Substitutes in the Barley Ration</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Incubators Used</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Number of Eggs Set March 31st</td>
<td>150</td>
<td>300</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>Per Cent of Eggs Fertile</td>
<td>87</td>
<td>90</td>
<td>92</td>
<td>92</td>
</tr>
<tr>
<td>Per Cent of Fertile Eggs Hatched</td>
<td>18.2</td>
<td>58.2</td>
<td>42.4</td>
<td>44.6</td>
</tr>
</tbody>
</table>

Cod-liver oil was found to be a valuable supplement to the
home-grown grains of barley, oats and wheat. It maintained birds
in better egg production and prevented nutritional roup. It greatly
improved the hatchability over that of the basal ration and main-
tained the birds at the peak of hatchability for a longer period of
time.

<table>
<thead>
<tr>
<th>TABLE IX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effect of Green Feed Substitutes in the Corn Ration</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Basal Ration</th>
<th>Basal Ration and Sprouted Barley</th>
<th>Basal Ration and Alfalfa Leaves</th>
<th>Basal Ration and Cabbage</th>
<th>Basal Ration and Sunflower Silage</th>
<th>Basal Ration and Cod-liver Oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Incubators</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>No. of Eggs Set</td>
<td>150</td>
<td>300</td>
<td>300</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>Per Cent of Eggs Fertile</td>
<td>89</td>
<td>92</td>
<td>92</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>Per Cent of Fertile Eggs Hatched</td>
<td>53.8</td>
<td>58.0</td>
<td>64.6</td>
<td>52.8</td>
<td>50.8</td>
</tr>
</tbody>
</table>
The green feed substitutes were more effective with the corn rations than with the barley rations, not so much in the increased hatchability as in the continued high hatchability. The barley rations supplemented with alfalfa, cabbage, and sunflower silage gave good hatchability for six weeks to two months, while the corn rations under the same conditions gave high hatchability during the entire incubation season.

**DIRECT SUNLIGHT AND HATCHABILITY**

Three pens of chickens were placed on experiment to determine the effect of direct sunlight on hatchability. Table X gives the hours of direct sunlight and the distribution over a period of four months. The hens were subjected to not less than twenty minutes and not more than two hours of direct sunlight at one time or on one day. The incubation of eggs started the last week in February and continued through the month of March. The first trial gave a hatchability of 23.8 per cent for Pen 1, 58.4 per cent for Pen 2, and 56.5 per cent for Pen 3. The second trial gave a hatchability of 18.3 for Pen 1, 62.2 for Pen 2, and 64.9 for Pen 3. Successive incubation trials during March showed a gradual decrease in hatchability for Pen 1, while that of Pen 2 and 3 remained the same.

<table>
<thead>
<tr>
<th>TABLE X</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hours of Direct Sunlight</td>
</tr>
<tr>
<td>Pen 1</td>
</tr>
<tr>
<td>October ..........</td>
</tr>
<tr>
<td>November ..........</td>
</tr>
<tr>
<td>December ..........</td>
</tr>
<tr>
<td>January ..........</td>
</tr>
<tr>
<td>February ..........</td>
</tr>
<tr>
<td>March ..........</td>
</tr>
<tr>
<td>TOTAL ..........</td>
</tr>
</tbody>
</table>
SUMMARY AND CONCLUSIONS

The altitude does not appear to be a factor in hatchability. The hatchability at high altitudes compares very favorably with that at low altitudes. The eggs from trapnest selected breeding stock hatched 66 per cent in February and 78 per cent during March of the same season.

The eggs from individuals of the same pen with almost identical production varied greatly in hatchability, in a few exceptional cases as much as zero and 100 per cent.

Moisture was found to be the most important factor in both natural and artificial incubation. The best hatchability has been obtained when the relative humidity in incubators averaged 50 per cent for eighteen days of incubation and 60 per cent or more at hatching time.

All makes of incubators tested were found to be adaptable to this altitude and climate when the relative humidity of the egg chamber was raised sufficiently to prevent excessive evaporation from the eggs. The best results in hatchability were obtained when the evaporation varied between 12 and 15 per cent for eggs not older than four days, and 12 to 13 per cent for eggs ten to twelve days old at the time incubation started.

Moisture supplied by means of water trays or sand trays raised the relative humidity in incubators to a point between 35 and 45. Additional moisture was necessary for successful incubation and was supplied by placing wet sponges on the egg trays. For mid-winter and mid-summer hatching, or in exceptionally dry seasons, overhead shelves in the egg chamber were filled with wet sponges.

The cooling of eggs was found to be especially valuable with the higher incubation temperatures. Cooling retarded development and slowed down the rate of evaporation.

The temperature requirement of chicken eggs is the same at high altitudes as near sea level, provided the relative humidity in the incubator is approximately 50 per cent. Experiments have demonstrated that the relative humidity and the egg temperature
are directly related: low relative humidity and low egg temperature, high relative humidity and high egg temperature.

Alfalfa was found to be the best winter green feed substitute. Sunflower silage was found to be a good substitute winter green feed, but two to three months were necessary to get fowls to eat it readily.

Cod-liver oil was found to be a valuable supplement to our home-grown grains of wheat, oats and barley. Cod-liver oil did not increase the hatchability in the corn rations over that of the green feed substitutes, but maintained the birds at the peak of hatchability during the spring and summer months.