RELATION OF CAFFEINE AND COFFEE TO HUMAN EFFICIENCY.*

BY RALPH HOLT CHENEY.

Efficiency and diet occupy a more prominent position in the public mind to-day than in all previous history. At the moment, caffeine beverages, especially coffee, are lauded or berated vigorously regarding their value in the diet in relation to human efficiency.

Based upon "whims and guesses," coffee has been praised or condemned for centuries. What is the scientific evidence "pro" and "con?" Historically, we find a prohibition edict by Khaine Beg, Governor of Mecca in 1511, who started a campaign which condemned coffee as an inebriating beverage forbidden by the Koran because the people frequented coffee houses rather than the mosques. Coffee and coffee houses were taxed by European governments as a source of revenue. Later, coffee houses were prohibited by Charles II of England as "Seminaries of Sedition." Coffee houses have served as gathering places for public discussions of governmental affairs. They were the predecessors of the boulevard cafés of Paris and the coffee-house taverns of England. This English prototype appeared in the United States where the coffee houses of Boston and New York harbored the instigators of the Boston Tea Party and revolutionary propaganda.

In spite of six hundred years of agitation associated with coffee, its consumption has increased constantly from an insignificant amount to three billion pounds annually, and its use has spread from the Abyssinian hillsides to world-wide consumption. Mocha coffee from the original home of the plant now supplies less than 3% of the seeds (coffee beans) of this sweet-pulped, cherry-like fruit which was introduced in America in 1717. Its cultivation has changed the economic map of several countries. Brazil has two billion coffee trees, Colombia a quarter billion, and the success or failure of the crop is the chief factor in the economic situation in these countries. Eighty per cent of the total gold value of Salvadorean exports is coffee. Although the plant is foreign to American soil, no better coffee is marketed to-day than the Colombian or Brazilian Santos from the Uplands where it is prepared by the most modern methods.

The United States consumes over one-half of all the coffee exported from the cultivated areas. New York City requirements annually total seventy million pounds, for which we pay thirty million dollars. Space limitation causes me to refer you to a book, "Coffee" (1), published by the New York University Press, for botanical characteristics; and also, for further details of the interesting, romantic history and economics of the plant and its beverage.

Undoubtedly, more scientific experimentation on the subject of caffeine and coffee effects has been conducted during the last twenty-five years than in all previous time. The results of such investigations are the only justifiable bases from which we may make our deductions regarding the physiological effects of the coffee as such, and of its individual ingredients.

Many investigators have reported that caffeine and caffeine beverages are undesirable for young children, neurotics, sufferers from severe arteriosclerosis, gastric hyperacidity, and other abnormal conditions. Likewise, the administration of caffeine for therapeutic purposes, such as stimulation of the coronary circulation in cardiac deficiency, are well known. May I make it perfectly clear, however, that the data presented in this paper is not concerned with the allergic effects of caffeine nor of the coffee beverage upon pathological conditions. This paper does not deal with its therapeutic value. All statements and figures refer entirely to *normal* physiology. The experimental animals and human subjects employed in the investigations were selected purposely from individuals of as nearly average good health as could be determined readily. In the caffeine work, the Merck product was used, and in the coffee work, the beverage was prepared by a rapid method (drip or vacuum) from recently torrified Colombian and Brazilian, high-grade beans.

Isotonic and isometric records of striated muscle fatigue curves of homologous muscles were made under non-treated and caffeine-treated conditions. The method and period of treatment were maintained uniformly throughout the series. Detailed discussions may be found in the writer's earlier papers, especially on the animal gastrocnemius behavior (2, 3).

Although Herxheimer (4) found that caffeine was of no benefit to the athelete, and P. T. Osborne states that caffeine actually interferes with the best muscular effects, the experimental data in this paper are more in agreement with H. C. Wood, Jr., (5) and others whose results offer definite evidence of improved muscular function.

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* New York Branch, A. PH. A.—See page 70, January JOURNAL.

An extended series indicated that better physiological coördination of the motor mechanism was obtained in the striated muscle action of the frog under the influence of low concentration of caffeine. According to the data presented in the August 1932, issue of the *Journal of Pharmacology and Experimental Therapeutics*, the optimum dosage (3) for these muscles for delaying fatigue was 0.1 mg. per Gm. body weight. Similar studies using the coffee beverage as such, in lieu of the purified caffeine, showed a parallel response for the gastrocnemius muscle.

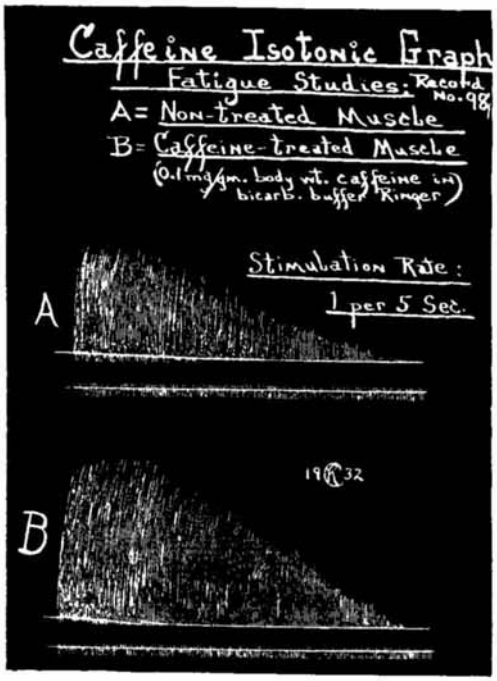

Fig. 1.—Caffeine isotonic graph.

A mathematical analysis of these fatigue curves in computing the XY values (Time *to* one-half fatigue × Height *at* one-half fatigue) demonstrated a greater XY value in both the caffeine and coffee curves as compared with the normal, non-treated result.

Under uniformly controlled circumstances, a study of the physical fatigue in human male subjects was attempted. The variable factor was the treatment; namely, the consumption of equal volumes of hot water, black coffee, or hot water plus caffeine (equivalent to the amount in the coffee) prior to the fatigue test involving a weight-lifting exercise every ten seconds to complete fatigue. Additional non-treated, starch capsule plus hot water, or plain hot water days were completed in order to correct for any practice, accommodation or experience factor which may have developed during the experimental tests. The Work Done was computed by the simple formula: WD = Weight (Gm.) × Height lifted (cm.) × Number of lifts. The result in gram-centimeters showed a sequence of an increasing amount of Work Done in the order of the non-treated or hot water day (least), coffee day, caffeine day (most). Attention was given primarily to the following physiological factors:

1. Blood-pressure variations: Systolic and diastolic.
2. Respiration: Rate and depth by pneumographic record.
3. Time required for a complete recovery of all factors after fatigue.

As compared with the non-treated fatigue values, the blood pressure and pulse variations were negligible; that is, their variation under the treated conditions was similar to their variation under the non-treated conditions. The increased respiratory rate and depth in the coffee instance indicated an increased oxygen consumption.

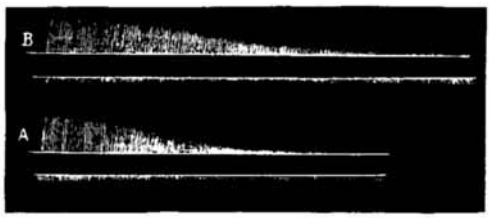

Fig. 2.—Caffeine isometric graph.

Fatigue Studies: Record No. 888.
A = *Non-treated* muscle; B = *Caffeine-treated* muscle. (0.1 mg./Gm. body weight caffeine in bicarb. buffer-Ringer) stimulation rate: 1 per 5 sec.

Several years ago (6), I conducted a series of tests to determine blood-pressure variations *without fatigue*, as influenced by caffeine and by coffee in comparison with normal behavior. This work has been repeated recently as an additional series. Similar and additional substantiating data were obtained. The accompanying graph separates the primary and secondary coffee effects

and indicates the fact that other substances are involved besides caffeine in the total coffee effects. Note that the caffeine or coffee increased the blood pressure only a few millimeters in excess of the ordinary luncheon (food) effect.

Although caffeine has been reported as a vaso-dilator of cerebral vessels, investigations (7) by Dr. P. G. Denker of Bellevue Hospital, caused him to conclude that caffeine definitely lowers the cerebrospinal pressure for half an hour. This fact is suggested by some workers as a possible explanation of the recognized relief induced by coffee in instances of mild hypertensive or nervous headaches, cerebral concussion, fractured skull and brain tumor. Sollman and Pilcher (8) reported in 1911 that caffeine causes vaso-dilation of the cerebral vessels. Wiechowski (9) had reported similar results in 1902 and claimed the dilation was due to a direct decrease in the tonus of the intracranial vessels. Such action with a rigid cranium would force out the cerebrospinal fluid and increase its pressure. Denker obtained the reverse results. With reference to the decreased cerebrospinal pressure it is significant that caffeine diuresis through glomerular action, involves primarily only an increase in the water content of the urine. This water loss must be lost necessarily from the body tissues through the lymph and blood. It must accomplish

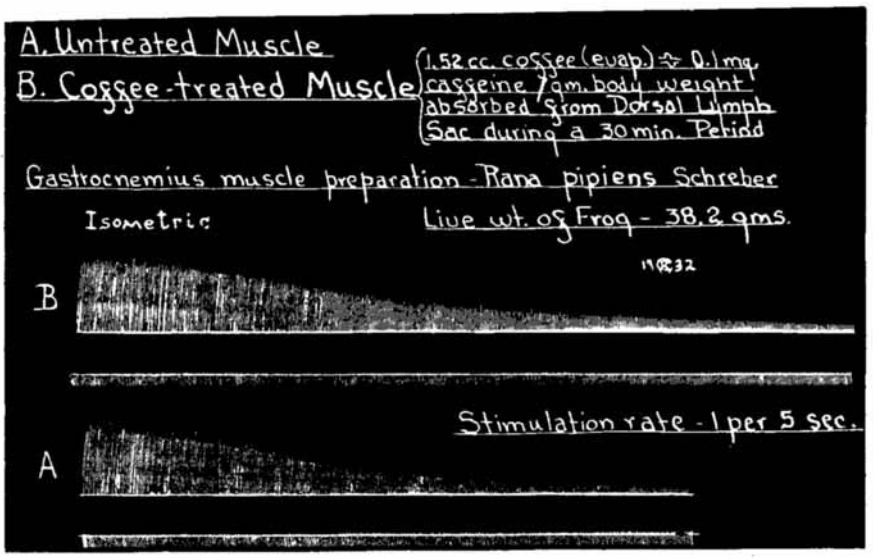

Fig. 3.—Coffee effect on muscular fatigue.

automatically, a reduction in brain volume with a consequent decrease in cerebrospinal fluid pressure.

The increased respiratory rate and depth, referred to earlier in connection with the fatigue as influenced by caffeine and coffee, is related also to an intercranial pressure. In 1913, Dixon and Halliburton (10) noted that reduction of carbon dioxide in the blood decreases the rate of cerebrospinal fluid secretion. Therefore, respiratory stimulation by caffeine or coffee, resulting in increased rate of carbon dioxide ventilation from the lungs, would decrease the rate of cerebrospinal fluid secretion. Apparently, caffeine lowers intracranial pressure by means of its combined pharmacologic actions rather than by any specific, single effect.

Dr. A. L. Winsor (11) of Cornell University, reported last October that coffee increases the salivary secretions in volume per unit of time. Such stimulation automatically improves digestion by making a greater enzymic mass available.

Professor Hollingworth's experimental series (12, 13) on the mental effects of caffeine and coffee are the best available studies on this phase of the subject. He reports a clearly distinguishable mental stimulation as evidenced by greater accuracy in the performance of work done.

Recently at Long Island University, a simplified psychodometer was devised to measure the reaction time in man with a visual-mental-physical coördination test. Quantitative data on

the relationship of caffeine and coffee separately to the normal reaction time were compiled. The subject was required to recognize a visual stimulus (light color), interpret it, and perform a muscular act in accordance with the color of the particular stimulus involved. Caffeine and coffee were each more effective in reducing the total reaction time in women than in men. The sequence in both sexes was as follows:

1. Non-treated tests required the longest reaction time.
2. Coffee—intermediate.
3. Caffeine-treated tests required the shortest reaction time.

In various physiological effects studied regarding muscular action, fatigue delay, respiration, pulse and mental effects, the sequence of minimum to maximum physiological stimulation is generally non-treated, coffee-treated, caffeine-treated. The absence of injurious effects in the majority of cases suggests the importance of optimum consumption. Excessive stimulation can be produced, but was not apparent in the amounts administered in the experiments upon normal animals and man, although the quantities given were in excess of average consumption. The absence of after-effects and accumulative effects is associated doubtlessly with the two primary facts:

1. Caffeine is combined with other chemical substances in coffee.
2. Caffeine itself loses CH_3 groups in the body and is excreted within a few hours in the urine as mono- and dimethyl xanthine.

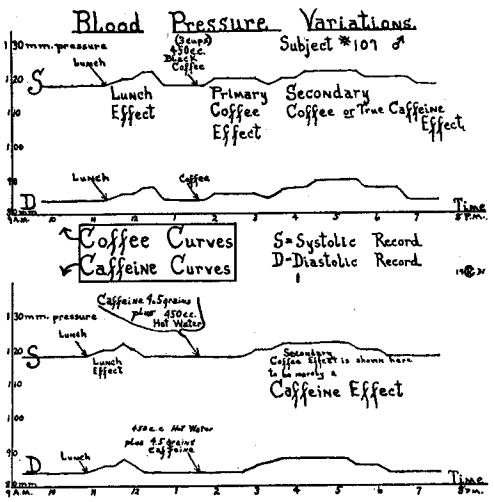

Fig. 4.—Blood-pressure variations: caffeine *vs.* coffee effects.

Likewise, Gutman (14), in agreement with this conception, observed that caffeine and coffee effects are not the same in abnormal persons (patients) showing allergic manifestations to coffee. Whereas caffeine may cause definite physiological disturbances, coffee may be well tolerated. Moreover, the action of coffee is not due solely to caffeine, but to the many compounds organized during the roasting process, and which are present in both decaffeinated and ordinary coffees.

Caffeine and coffee increase blood pressure very few millimeters, respiration and oxygen consumption slightly, and stimulates the brain and other parts of the central nervous system. These stimulants also delay fatigue and lower the cerebrospinal pressure. Caffeine is less effective in the coffee beverage than separately. Neither complex, caffeine nor the coffee beverage as such, can replace nutritive metabolism in the normal health of the tissues. It has been reported that both complexes increase basal metabolism; hence, food should always be taken regularly at the customary periods if the reserve forces of the body, which are reduced by increased metabolism, are to be replenished properly. Nevertheless, many people labor under the misconception that coffee has the ability to replace food merely because its stimulating action persists for several hours after consumption. It is an aid to functional efficiency, not a substitute for body fuel.

The variations from the normal due to coffee stimulation are slight and, in the reasonable amounts consumed ordinarily, are far below the maximum physiological disturbances, for the correction of which the body is equipped by nature to adjust itself without injurious effects.

Apparently, the delicate correlation between the increased blood flow and the increased respiratory rate accomplishes, in a fortunate sequence, *both* the more rapid removal of fatigue products from the body tissues to the blood; and, the greater purification (oxidation) of the blood

volume per unit time in the lungs. Fatigue, due to the accumulation of waste products in the tissues, is correspondingly delayed. Caffeine separately or in the coffee beverage, stimulates the circulation and respiration. The increased activity of one of these systems without a parallel response by the other, would be injurious. The stimulation of both synchronously, produces or "sets" the body metabolism at a higher level of physiological efficiency. That the body readily adjusts itself to the level of performance without injury is evidenced by the fact that the recovery time of the fatigue is practically identical with conditions subsequent to normal fatigue.

The bulk of available experimental data seems to indicate that the majority of the population may take advantage of this beneficial aid to body metabolism. Every debatable question has its "pro" and "con." Each of us has a caffeine and coffee tolerance which must be determined individually, and our consumption governed accordingly.

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HOSPITAL SALES EXEMPTED FROM CODE RESTRICTIONS.

Hugh S. Johnson, Administrator for Industrial Recovery, has issued the following order effective from February 2nd:

"Pursuant to authority delegated to me by executive orders of the President, including Executive Order No. 6543-A, dated December 30, 1933, it is hereby ordered that those members of industries subject to codes of fair competition who sell or may sell supplies or materials to hospitals of the United States which are supported by public subscription or endowment, and not operated for profit, within the limitations hereinafter provided, be and they are hereby exempted from compliance with provisions of such codes governing sales; provided, however, that the exemption hereby granted shall be limited to and operative only in connection with such sales made by such members to such institutions; that nothing in this order contained shall relieve any such member at any time from the duty of complying with all other provisions of such codes; and that this order shall not become effective for a period of ten days in order that consideration may be given to the objections, if any, of interested parties thereto. At the expiration of such period this order shall become effective unless I, by my further order, otherwise determine."
