~INTRODUCTION~

Energy plays a significant role in biological systems. It is a resource necessary for the propagation and maintenance of highly ordered physiochemical systems, which include reproductive activity too (Walsberg, 1983). Reproduction is an energetically expensive phenomenon. In majority of birds it is periodic in nature i.e. when the proper environmental conditions appears birds put all their physiological reserves into an intense and concentrated effort to produce the next generation. These condition in majority of cases being cyclic annual appearance of favourable environmental circumstances, majority of birds show a distinct annual reproductive cycle and hence they breed at such time of the year when survival rate of the young ones is maximum or their reproductive activities coincide with a season that is most advantageous for producing offspring as well as gives maximum stress to parents (Murton, 1975). Successful reproduction demands the temporal organization of gamete preparation in relation to mate and environmental resources of energy in the form of food (Murton and Westwood, 1977). Reproduction demands increase in daily dietary energy intake, which may vary quantitatively and qualitatively during different reproductive phases. Hence, for a particular avian species, reproductive period and pattern is by and large defined and is of limited duration (Lofts, 1975). Breeding season of a species is defined as when it has eggs or young in the nest (Perrins and Birkhead, 1983) and during this period superfluous time and energy are required which remain after the basic daily metabolic requirement of growth and maintenance of a bird (Murton & Westwood, 1977). Various adaptations are shown by birds to combat increased energy demands. In smaller passerines like Zebra finches, compensation for energy cost of egg production is achieved by reducing energy expenditure on locomotor activity thus, reallocating their total energy budget without modification in daily food intake (Williams and Ternan, 1999), whereas in some other species energy is stored before starting breeding activities (Jones and Ward, 1976) or some may depend upon regular food supply (Bharucha, 2002). The reports indicate that birds depend on different patterns of energy procurement during breeding season. Reserve users like Lesser Snow Goose arrives at their breeding ground about 20% heavier than their normal weight and the amount of reserve is closely related to the size of clutch produced, whereas in the daily surplus users Red-billed Quelea, sufficient food is available each day to produce its complete clutch (Perrins and Birkhead, 1983). Energetics associated with breeding activities are achieved by synchronization of the endogenous controlling mechanism by a variety of environmental cues to which a particular species has evolved a response. These cues give predictive clues (proximate factors) like temperature, weather, nest-site, nest material, food supply etc. to the bird and act as promoters or repressors (Welty, 1990).

Photoperiodism also plays an important role in breeding. It is a physiological mechanism that brings seasonality of reproduction in birds. Animals synchronize their internal rhythm of body functions with the external chronology of the day and night cycle (Murton and Westwood, 1977) and other environmental stimuli. Increasing day-length directly stimulates gonadal growth (Dawson, 2001) viz. voluminous increase in testis and ovary size, which are otherwise in recrudescent phase. Increased photoperiod also provides increased time for procurement of food for the increased demand of energy. The other stimuli may be abundance in availability of food for young.

In the present study the energy metabolism and utilization of some of the major metabolites of the body, during different phases of reproductive cycle, in two closely related long day breeding passerines belonging to family Sturnidae are investigated. The species selected for the study are, the Bank myna *Acridotheres ginginianus* and Brahminy myna (Black Headed myna) *Sturnus pagodarum* commonly seen in the area. The former is a resident species of continental and peninsular India, neighbourhood of human habitations, whereas the later is widespread in most of India and is found in open deciduous forest, scrub jungle and near cultivation and human habitations too (Ali and Ripley, 1983; Grewal, 1995). For both the species of mynas breeding season coincides with long days with increase in insect population at the onset of monsoon. Both the bird species are known to feed their nestlings predominantly with animal matter (mainly insects) that is 95.59% by frequency in Bank myna (Parasara *et al.,* 1990) and 81.57% by frequency in Brahminy myna

(Patel *et al.,* 1992). Both the species are hole nesters; Bank myna is a colonial nester and builds nests in earthern riverine banks, sides of wells, under bridges and is seen to be nesting in broken walls in the vicinity of water body (Ali, 1979; Khera and Kalsi, 1986; Narang and Lamba, 1984; Personal observations). It is a gregarious bird with communal roosting habits exhibited throughout the year. Only during the breeding season the incubating and brooding females sleep solitarily in the nest during night hours (Khera and Kalsi, 1986). Otherwise both the sexes take part in feeding the young. Being an omnivore species, Bank myna feed on fruits, grains and insects (Ali, 1979) and are easily found on Municipal garbage dumps and railway stations in large numbers and also found to be feeding on oily human left over. Unlike Bank Myna, Brahminy myna is a solitary hole nester with selective omnivore habits. These birds prefer taking to the nest holes of other birds, sometimes they even drive away the Barbets from their nests, (Panicker, 1980). They are also seen nesting successfully in nest boxes and roost in association with other mynas. They feed on fruits of Lantana, Zizyphus, Wild Figs, nectar of Erythrina etc. and insects like grasshoppers, moths, caterpillars etc (Ali and Ripley, 1972; Narang and Lamba, 1984).

In the present study the energy metabolism in this two closely related species of birds (Fam: Sturnidae), with differences in their food preference and nesting habits have been evaluated. The reproductive cycle of both the species of mynas in Baroda (Longitude 72.3°13'E, Latitude 22° 18'N) is considered in four phases viz. Feb-Apr as pre breeding (Pre-Br), May-Jul as breeding (Br), Aug-Oct as post breeding (Po-Br) and Nov-Jan as non breeding (Non-Br) seasons as per Padate (1990) and Sapna (2002). In both the sexes of the above mentioned passerines certain variations in biochemical parameters related to carbohydrate metabolism were investigated in three tissues viz. liver, intestine and kidney, over the reproductive cycles.

Liver has a key role to play in different metabolic activities like, glycogen synthesis, HMP shunt pathway, glycolysis, lipogenesis, lipolysis, protein synthesis, and gluconeogenesis. During a specific phase of reproduction, as and when, an essential metabolite is needed it is mainly synthesized in the liver. Thus, liver plays an important role in the assimilation and treatment of absorbed food and shows metabolic and enzymatic adaptations. Hence it may be said that, depending on the diet and physiological condition of the bird metabolism in liver is adjusted hence, liver is one of the major tissue studied. The second tissue studied is the intestine, the principle organ where chemical digestion of food takes place. It is a part of digestive system that functions both as a secretary organ as well as digestive chamber (Ziswiler and Farner, 1972). It plays an important role in absorption and transfer of nutrient materials from lumen into the blood. The capacity of the intestine to absorb nutrients appears to be influenced by the pattern of feeding and caloric intake of the animal (Reiser, 1976). The third tissue studied, kidney plays an important role in general metabolism due to its involvement in glucose homeostasis through gluconeogenesis (Shen and Mistry, 1979; Watford, 1989; Cano, 2002), a mechanism where glucose is produced from non-carbohydrate precursors like proteins, fats etc. This is usually switched on during starvation or when diet lacks carbohydrates (Mehta, 1985).

The energy demands during the different reproductive phases should depend on the metabolic changes based on shift in rates of synthesis of enzymes, their degradation, quantum and nature of factors that activate the whole enzyme cascade. The present study aims to deal with variations in enzyme activities mainly related to carbohydrate metabolism and involvement of some important metabolites in energy metabolism in relation to reproductive cycle in three metabolically important tissues mentioned earlier in two closely related omnivore species of birds which show difference in food preferences.

Glycogen is a polymorphic form of carbohydrate. The fate of dietary carbohydrate is either to get metabolised to carbon dioxide and water with release of energy or to get polymerised and stored or to be converted to lipoid moieties. Glycogen is present in almost all tissues of birds and mammals as a carbohydrate reserve, liver being the richest storage organ. In liver glycogen is stored as a readily available source of energy for extra-hepatic tissues and mobilized according to the peripheral needs. The relation of glycogen stores with difference in the expenditure of energy for breeding activities is explored.

Degradation of glycogen (Glycogenolysis) is accomplished by a rate-limiting enzyme, phosphorylase or Glycogen phosphorylase (GP) that plays a strategic role in glycogenolytic pathway (Mayes, 2000). It is the initial catalytic reaction in the chain of chemical events that leads to the phosphorylative degradation and utilization of glycogen (Stetten *et al.,* 1960). Hence, the level of the enzyme present in a tissue or the variations in its activity would apparently indicate the rate of glycogenolysis. Increase in the phosphorylase activity can be considered as an index of extent of glycogen depletion, and indicates increased glycogenolysis (Cahill *et al.,* 1957). The increased GP activity of the tissue denotes increased energy demands for the various activities and also the use of carbohydrate as the chief fuel for instant energy.

Another enzyme which catabolizes the final step of glycogenolysis and gluconeogenesis is glucose-6-phosphatase (G-6-Pase) enzyme complex located in the endoplasmic reticulum (Burchell, 1996). It occurs mainly in glycogenic tissues such as liver, where it plays an important role in releasing glucose into the blood stream by hydrolyses of glucose-6-phosphate to glucose and phosphate (Mayes, 2000; Plewka *et al.,* 2000). This enzyme is active when the blood glucose levels are low and triggers the glycogenolytic pathway.

Another enzyme studied is Succinate Dehydrogenase (SDH), a key enzyme in TCA cycle, which plays a pivotal role in metabolism and is an important mitochondrial marker enzyme (Mayes, 2000). The activity of SDH can be an index of the oxidative metabolism and production of ATP molecules in a tissue and of an active TCA cycle. The TCA cycle is escalated and attains a maximum momentum to supply sufficient quantity of the energy rich ATP molecules required for the active synthesis of pivotal metabolites such as lipids, glycogen etc. as well as for carrying out different activities in conformity with the needs of the tissue (Patel, 1979). TCA cycle replenishes the supply of energy rich ATP molecules for the enzyme Adenosine Triphosphatase (ATPase), involved in high-energy phosphate metabolism responsible for splitting of ATP to ADP and high-energy phosphate in the form of utilizable free energy (Mayes, 2000). Thus, operations of TCA cycle and ATP utilization can be deduced from the activities of SDH and ATPase. Both these enzymes have been studied together in the present work.

Another group of enzymes that is taken up for the present investigation are non-specific acid phosphatase (AcPase) and alkaline phosphatase (AlkPase). Phosphatases are involved in various aspects of cellular metabolism. They are categorised under phosphomonoesterases and since they hydrolyse a number of phosphate esters, they are termed as non-specific phosphatases.

AcPase is active at an acidic pH whereas AlkPase, a stably anchored enzyme at the cell surfaces through covalent linkages, is active at an alkaline pH. They are known to play significant role in secretion of digestive enzymes and absorption of digested food (shah *et al.,* 1975). This group of enzyme help in transport of metabolites across the membrane and hydrolyses phosphate esters (Patel, 1979) hence, act as transferases and hydrolyses according to the site of localization. These enzymes according to their presence at a particular site are involved in variety of cellular activities like, absorption, cellular phagocytosis, phosphorylation, protein synthesis, carbohydrate metabolism and phosphate transfer in DNA metabolism. Their role in liver of birds with different feeding habits has been found to vary considerably (Shah *et al.,* 1972). Though both the species of birds studied are omnivore, they show difference in their food preferences and also change the diet seasonally, depending on the availability of food (Narang and Lamba, 1984; Simwat and Sidhu, 1974). Bank myna feeds on anything and everything available whereas Brahminy myna prefers mainly fruits or insects. By studying AcPase and AlkPase, an attempt is being made to find, if there exists any, species-specific differences.

Proteins play central role in cell function, with their involvement in cell structure and one-fifth of the fat free body of mammals and birds consists of proteins and plays a functional role in supplying energy during the course of their degradation (Griminger and Scanes, 1986). Excess of dietary amino acids are not excreted, instead they are converted to precursors of glucose, fatty acids and ketone bodies, hence, are called as metabolic fuels (Voet *et al.,* 1998).

Lipids are another major group of metabolites found in all cells and play an important role in diverse physiological processes such as energy production, reproduction, migration etc. Total lipid includes four principal forms: triglycerides, phospholipids, cholesterol and free fatty acids. The triglycerides or neutral fats are fatty acid esters of glycerol; serve as a major store as well as source of energy. In the present study variations in lipid content during different phases of reproductive cycles in both the species and sexes of mynas, with carbohydrate metabolism and protein content of the tissues are considered. Cholesterol, a sterol present in tissues and plasma lipoproteins (as free cholesterol and cholesteryl esters), plays vital role in fatty acid transport, as a precursor of steroid hormones and bile acids, in cell membrane structure etc. Pathways of lipid and cholesterol metabolism meet at a common intermediate, acetyl Co-A, and glycerol of fat can join the reversible pathway of carbohydrate metabolism, which indicates close integration of lipid and carbohydrate metabolism (Patel, 1982). Hence, cholesterol content in three tissues has been measured with reference to energy metabolism, in two relatively similar species of birds having differences in feeding and breeding activities are investigated.

CRUX OF THE STUDY

The gonads of a seasonal breeder undergo preparatory changes during the sojourn of breeding cycle. These changes, mostly anabolic in nature, peaks during sexually active phase, which is the climax of the sequence of events and later culminates in the form of regression of gonads. There is no dearth of literature available highlighting various aspects of avian reproduction and the gonads of avian species are also studied extensively, however the information on energetics associated with the reawakening of gonads and preparatory processes related with the onset of breeding activities in wild species are scant. Hence, the study is an attempt to investigate the energy released through carbohydrate metabolism and its utilization by two sturnids, Bank myna *Acridotheres ginginiaus* and Brahminy (Black headed) myna *Sturnus pagodarum*, in the three metabolically important tissues viz: liver, intestine and kidney, during the various phases of breeding cycles. This is investigated by assaying certain important enzymes involved in carbohydrate metabolism along with protein, lipid and cholesterol, the important metabolites, which are responsible for realising energy whenever needed, by getting degraded into smaller moieties, to be used by different tissues during the sojourn of reproduction.

PLATE – I

(A) BANK MYNA *Acridotheres ginginianus*

(B) BRAHMINY MYNA *Sturnus pagodarum*

PLATE I

PLATE – II

(b) Breeding colony of Bank myna in holes of a concrete bridge.

(c) The nest of Brahminy myna, the solitary nester, exhibiting nest guarding behavior.

PLATE II

PLATE – III

(E) Bank myna feeding on human left over
from garbage.

(F) Normal foraging activity of Brahminy myna.

PLATE III

PLATE – IV

(G) Bank myna feeding at railway station.

(H) Brahminy myna feeding on nectar.

PLATE IV