Regulation of the Growth of Poultry Skeletal Muscle

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Introduction

The long-term research goals in Drs. Velleman’s and McFarland’s laboratories are to improve the efficiency and the rates of muscle (meat) accretion in poultry and to identify the biochemical parameters that might improve selection criteria of poultry. The Midwest Poultry Research Program has identified “growth and body composition” including muscling as a priority research focus. The major focus of Drs. Velleman’s and McFarland’s research programs is to elucidate the biological mechanisms which regulate the growth of skeletal muscle in poultry and provide the information so it can be transferred to the poultry industry. Drs. Velleman and McFarland interact with the Ohio and South Dakota Poultry Associations as well as major poultry companies including Cobb-Vantress, Maple Leaf Ducks, and Aviagen to help transfer their research results to the industry. Major factors influencing the growth of muscle are the extrinsic environment surround muscle cells, the extracellular matrix (ECM) (Dr. Velleman’s research emphasis), and polypeptide growth factors (Dr. McFarland’s research emphasis). It has become increasingly clear that these two components of growth are intimately tied together and each interacts with and regulates the activity of the other. These findings have contributed to the development of a very productive collaborative relationship between Drs. Velleman and McFarland for the past 18 years and have resulted in many papers published in referred journals.

Materials and Methods

Postnatal/posthatch skeletal muscle development is dependent on the activity of myogenic satellite cells residing between the plasma membrane and basement membrane of muscle fibers. Therefore satellite cells are the most appropriate cell system to utilize in examining mechanism of skeletal muscle growth in poultry and in other vertebrates. Many pure satellite cell lines have been developed and utilized in the McFarland and Velleman laboratories for our ongoing studies. Satellite cells will
proliferate and differentiate to form multinucleated myotubes (immature muscle fibers), simulating muscle development in vivo. The following are photographs of proliferating (left) and differentiating (right) turkey satellite cells.

Results and Discussion

We published the following manuscripts detailing the research sponsored in part by the Midwest Poultry Research Program during this period. In the previous preliminary progress report we detailed the findings of the first and second manuscript. We also described the effects of fatty acids on syndecan-4 and glypican-1 expression and their effects on proliferation and differentiation. A manuscript covering this latter data is nearly ready to be submitted for publication.


Song, Yan, Douglas C. McFarland, Sandra G. Velleman. Effect of syndecan-4 covalently attached chains on turkey satellite cell proliferation, differentiation, and responsiveness to fibroblast growth factor 2. (submitted)

Glypican-1 is a cell membrane heparan sulfate proteoglycan that is composed of a core protein and covalently attached glycosaminoglycan (GAG) chains and N-linked glycosylated (N-glycosylated) chains. The glypican-1 GAG chains are required for cell differentiation and responsiveness to fibroblast growth factor 2 (FGF2). The role of glypican-1 N-glycosylated chains in regulating cell activities has not been reported. The objective of the current study was to investigate the role of glypican-1 N-glycosylated chains and the interaction between N-glycosylated and GAG chains in turkey myogenic satellite cell proliferation, differentiation, and FGF2 responsiveness. The wild-type turkey glypican-1 and turkey glypican-1 with mutated GAG chain attachment sites were cloned into the pCMS-EGFP mammalian expression vector and were used as templates to generate glypican-1 N-glycosylated 1-chain and no-chain mutants with or without GAG chains by site-directed mutagenesis. The wild-type glypican-1 and all glypican-1 N-glycosylated 1-chain and no-chain mutants with or without GAG chains were transfected into turkey myogenic satellite cells. Cell proliferation, differentiation, and FGF2 responsiveness were measured. The overexpression of glypican-1 N-glycosylated 1-chain and no-chain mutants without GAG chains increased cell proliferation and differentiation compared with the wild-type glypican-1 but not the glypican-1 N-glycosylated mutants with GAG chains attached. Cells overexpressing glypican-1 N-glycosylated mutants with or without GAG chains increased cell responsiveness to FGF2 compared with wild-type glypican-1. These data suggest that glypican-1 N-glycosylated chains and GAG chains are critical in regulating turkey myogenic satellite cell proliferation, differentiation, and responsiveness to FGF2.

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Song, Yan, Douglas C. McFarland, Sandra G. Velleman. Effect of syndecan-4 covalently attached chains on turkey satellite cell proliferation, differentiation, and responsiveness to fibroblast growth factor 2. (submitted)

Syndecan-4 is a cell membrane heparan sulfate proteoglycan that functions in muscle growth, development, and regeneration. It is composed of a core protein and covalently attached glycosaminoglycan (GAG) chains and N-linked glycosylated (N-glycosylated) chains. The GAG chains are not required for syndecan-4 to regulate cell responsiveness to fibroblast growth factor 2 (FGF2). N-glycosylated chains are thought to be required for protein folding and cell membrane localization. It is possible that syndecan-4 N-glycosylated chains play an important role in regulating myogenic satellite cell activities. The objective of this study was to investigate the role of syndecan-4 N-glycosylated chains and the interaction between N-glycosylated chains and GAG chains in turkey myogenic satellite cell proliferation, differentiation, and FGF2 responsiveness. The wild type turkey syndecan-4 and the turkey syndecan-4 with GAG chain attachment sites mutated were cloned into a pCMS-EGFP vector and used as templates to generate syndecan-4 glycosylated one-chain, and no-chain mutants with or
without GAG chains. The wild type syndecan-4, all of the syndecan-4 N-glycosylated one-chain and no-chain mutants with or without GAG chains were transfected into turkey myogenic satellite cells. Cell proliferation, differentiation, and responsiveness to FGF2 were measured. The over-expression of syndecan-4 N-glycosylated one-chain and no-chains mutants with or without GAG chains generally did not change cell proliferation, differentiation, and responsiveness to FGF2 compared to the wild type syndecan-4 except that the over-expression of syndecan-4 N-glycosylated mutants without GAG chains increased cell proliferation at 48 and 72 h post transfection. These data suggest that syndecan-4 functions in an FGF2 independent manner, and the N-glycosylated and GAG chains are required for syndecan-4 to regulate turkey myogenic satellite cell proliferation but not differentiation.

These experiments demonstrate the importance of growth factors and their interaction with the extracellular matrix, especially the proteoglycans, in regulating poultry skeletal muscle growth and development. An improved understanding of how these important components regulate skeletal muscle development in poultry and other meat animals will lead to strategies to increase production efficiency.